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The Development of Astronomical Photometry*

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INTRODUCTION

To the astronomer engaged in statistical studies, stellar magnitude is a measuring stick with which to sound the depths of space. To the astrophysicist, stellar magnitude, or, in a broader sense, stellar brightness, is a caliper with which to measure stellar diameters; a thermometer with which to measure stellar temperatures; a probe with which to examine stellar interiors and atmospheres. The greater portion of our quantitative observational knowledge of individual celestial objects, aside from information on their motions, is derived in some way from photometric measurements. And likewise upon the work of the observer engaged in photometry must be based our ideas of the dimensions and structure of our galaxy and of the universe. Involved in studies of celestial objects of all types, both singly and in groups of varied sizes, photometry is a subject of major importance in the science of astronomy.

From the historical point of view the subject of astronomical photometry may be divided into four periods overlapping in time, but each clearly characterized by certain photometric techniques.

Period I. During the first period of astronomical photometry, estimates of stellar brightness[1] were made by unaided eye, or by eye with the aid of a telescope after that instrument was introduced into astronomy in 1609. Throughout most of this first period no standard scale of brightness existed, and each observer, though he based his work on that of previous observers, largely defined his own system or scale of brightness. Because of this fact, large systematic differences are frequently found between the results of different observers of this period.

A few observers active during the first photometric period were interested in the apparent colors of the stars as well as in their brightness. During the last half of the nineteenth and first few years of the twentieth centuries there were published several rather extensive catalogs of

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[1] The general physical definition of brightness involves a consideration of the radiant energy emitted per unit emissive area as projected on a plane normal to the line of sight. A star, of course, shows no sensible disc and so has no sensible area. By brightness we mean here the intensity of the response of the retina of the eye to the light received by the retina from a star.

star colors determined by eye estimates.

Period II. The second period of astronomical photometry began the first time stellar brightness and color were measured by some photometric instrument rather than estimated by eye. Generally, but not necessarily, the photometric devices with which these measurements were made were used in conjunction with a telescope. Probably the greatest single advance made during this period was the mathematical specification and practical establishment of a standard brightness scale of an absolute type.

Period III. The third period of astronomical photometry began with the application of photography to the problems of photometry, and is now in full progress. During this period there have been established, by photographic means, accurate brightness scales for various wavelength ranges corresponding to those of the ordinary (blue sensitive) plate, the human eye, and to several color filter-photographic plate combinations. A number of methods for determining star colors on a large scale have been devised, and the procedures of spectrophotometry have been perfected.

Period IV. The fourth and latest period of astronomical photometry is marked by the use of the various so-called physical photometers in the determination of stellar brightness and color and in the study of the "total" radiation of celestial objects. The introduction of these new instruments has enormously extended the scope of our observations both in range and accuracy. Probably the most spectacular advance made through the use of these devices is the increase in the accuracy with which the brightness of one star may be compared with that of a neighboring star.

PERIOD I

The first photometric period, originating with the work of Hipparchus and other unremembered observers, had, at the turn of the century, held the dominant position in the field of astronomical photometry for two thousand years. Notable among the achievements of the period are the first critical photometric estimates of Ptolemy, the revision of the *Almagest*, by al-Sûfi, the work of Tycho and of Bayer. During the first photometric period Galileo introduced the telescope as a tool of astronomical research, and Ptolemy's system of magnitudes was extended to the telescopic stars by Galileo himself, by Flamsteed, Lalande, Piazzi, Bessel, and others, frequently as by-products of meridian circle observations of stellar positions. Sir William Herschel devised his step-degree method of estimating stellar brightness by forming short sequences of stars, ordering them according to apparent brightness, and indicating the degree of difference between succesive sequence members by means of symbols. Later, Argelander, using "grades" instead of symbols made use of the same method for estimating the light changes of variable stars, a subject growing in importance at that

period.[2] In 1843 Argelander published his *Uranometria Nova,* which contained positions and magnitudes (determined by eye estimates) for all objects visible to the unaided eye from the latitude of Bonn. This catalog was revised by Heis in 1872 to include fainter stars (*Atlas Coelestis Novus*), and in 1879 was extended by Gould to include the stars of the southern hemisphere (*Uranometria Argentina*).

While this revision and extension were in progress, Argelander continued his work in astrometry and photometry and completed the observations that resulted in the publication of the first three volumes of the *Bonner Durchmusterung* (1859, 1861, 1862). The *B.D.*, which contained entries for 458,000 stars brighter than magnitude 10.5 and north of declination —2°, was later extended to include stars north of declination —23° by Argelander's successor at Bonn, Schönfeld, in 1886 (the *Südliche Durchmusterung*), and still later, during the period 1885-1908, was extended to declination —62° by J. M. Thome at the Argentine National Observatory (the *Córdoba Durchmusterung*).

The publication of these extensive *Durchmusterungen,* which, taken together, contain positions and magnitudes for more than a million stars, climaxed, and brought to a close the major portion of the first period of astronomical photometry.

PERIOD II

Thus, at the beginning of our century the first period of photometry had only recently ended.[3] As we can now look back on that first period from our present vantage point in time it is evident that the observers of that period were very generally limited with respect to the accuracy with which they could establish magnitude scales, and it now seems probable that those scales that had been established by the end of the first period had very nearly reached the ultimate attainable accuracy that could be expected without the introduction of entirely new photometric procedures, that is, without the introduction of measuring instruments to aid or supplant the eye.

The introduction of such measuring instruments marked the beginning of the second period of astronomical photometry. Chronologically, this period began in 1725, when P. Bouger, in measuring the brightness of the sun and moon by means of a simple illumination photometer in which he employed a standard candle as a source, made the first known application of a photometric instrument to an astronomical problem.

[2] It is worthwhile mentioning that Sir John Herschel, the son of Sir William, further perfected the method of sequences and by means of it determined the magnitudes of a group of southern stars. Two other astronomers—Pogson and Pickering—have suggested methods of determining magnitudes of variable stars which are very similar to those proposed by Herschel and Argelander.

[3] The word "ended" here implies "ended as a major movement in astronomy." Valuable work in the field of photometry is still being done by the methods of the first period—work primarily in the field of variable stars carried out by the members of the AAVSO and similar organizations.

A few years later, in 1740, A. Celsius and A. Tulenius of the Upsala Observatory made the first measurements of stellar magnitudes with a crude extinction photometer.

THE GENERAL DEVELOPMENT OF PHOTOMETRY IN THE SECOND PERIOD

It was not until nearly a century after these experiments had been completed, however, that we find any important application of a photometer to an astronomical problem. In 1836 Sir John Herschel invented his "astrometer," a device for measuring the brightness of stars by comparing them with a minified image of the moon, and made use of his device to determine the light ratios of a number of southern stars.[4]

Starting at the time of Herschel there was a decided quickening of pace in the field of astronomical photometry. While Herschel was constructing his astrometer, C. A. Steinheil at Munich was devising a somewhat similar but more refined light-measuring instrument known as the prism-photometer. This device consisted of a small telescope with a divided objective, the two halves of which could independently be moved along the optical axis of the telescope. This motion allowed the relative intensities of two images[5] which were diffused into small discs of sensible area by being out of focus, to be varied. From the relative positions of the two half-objectives when so adjusted that the images were of equal intensity, the relative brightness of the stars could be computed.

In 1850 Arago showed how the principles of the polarization of light might be utilized in the design of an astronomical photometer, and shortly thereafter J. F. C. Zöllner devised a photometer that embodied Arago's suggestions. In contrast to Steinheil's instrument, in which diffuse out-of-focus images of two stars were compared, Zöllner designed his photometer so that the focal image of a real star was compared with the focal image of an artificial star, which, through optical means, was made to appear in the same field of view. The brightness of this artificial star could be accurately controlled by the relative position angles of two Nicol prisms through which the light forming the artificial star passed.

Zöllner published the first extensive series of measurements (226 stars) with his photometer in 1861. In the years that followed, a number of observers, chiefly Pierce, Wolff, Müller, Kempf, and Lindemann, used photometers of the Zöllner type with very satisfactory results.

During the years 1881-1885 C. Pritchard, aided by W. Plummer and B. C. Jenkins, made use of an extinction photometer (similar in princi-

[4] It is interesting to note in passing that in 1916 H. N. Russell reversed Herschel's procedure and, assuming the magnitudes of the stars to be known from later sources, made use of Herschel's measurements to determine the magnitude of the moon. The result obtained by Russell is of a high order of accuracy.

[5] One image from each half of the objective. A system of prisms before the half-objectives allowed stars in different parts of the sky to be viewed simultaneously.

ple to that used almost a century and a half previously by Celsius and Tulenius) in the determination of the magnitudes of nearly 3000 stars located between declination limits +90° and —10°. The device used by Pritchard was very simple indeed, and consisted of a neutral absorbing wedge arranged to slide in a groove on the cap of the eyepiece of a telescope. To make a measurement with this device, the observer placed his eye near the wedge and determined the point on the wedge at which the star under consideration just disappeared from view. The position, on the wedge, of this point of disappearance served as a measure of the star's magnitude. While many magnitudes were determined with this instrument over a period of some years, the principle of this photometer was never very satisfactory. From an analysis of Pritchard's catalog, the *Uranometria Nova Oxoniensis,* it appears very definitely that there is a very strong tendency for the observer to judge the stars to be too bright, that is, to continue to think he sees a star beyond the point where it has actually disappeared from his view.

At the time that Pritchard was making the observations for his *Uranometria,* work in the field of photometry was in progress in America at the Harvard College Observatory. Between 1871 and 1879 a number of experimental photometers based on Arago's principle were designed and used at Harvard under the direction of E. C. Pickering. From the experiences gained with these various experimental photometers finally evolved the famous meridian photometer, which embodied constructional details similar to both Steinheil's prism photometer and Zöllner's polarizing photometer.

The meridian photometer, the first model of which was constructed in 1889, consisted of a horizontal telescope that had two objectives of the same diameter and approximately of the same focal length, and which was pointed either east or west. The foci of these objectives were coplanar, and a system of reflectors before the objectives allowed two star fields on or near the meridian to be superimposed and viewed through a single eyepiece. One objective was used to view a so-called standard star near the pole, the other to view some particular star for which the magnitude was desired. Near the common focus of these objectives was placed a double-image prism which doubled each cone of light from each objective, and plane polarized the light in each of these two beams, the planes of polarization being at right angles. The apparatus was so designed that two beams (one from each objective) nearly coincided as they emerged from the double-image prism, and these beams entered the eyepiece. The two unused beams of light (again one from each objective) which did not enter the eyepiece were intercepted by an appropriately placed diaphragm. The beams of light which entered the eyepiece, one from each objective, were plane polarized at right angles; in front of the eyepiece was a Nicol prism. By rotation of this Nicol prism, the two images under consideration, one of

the standard star, the other of the star being compared with this standard, could be made to appear of the same brightness. When so adjusted, the position angle of the Nicol was a measure of the difference in brightness between the two stars.

The principal results of many years of observing with meridian photometers of two- and three-inches aperture are collected in *Annals of the Harvard College Observatory,* Volume 50, the *Revised Harvard Photometry,* which contains photometric visual magnitudes for all stars brighter than magnitude 6.5, in all, some 9,110 stars, and Volume 54, the *Supplement to the Revised Harvard Photometry,* which contains photometric magnitudes for 36,682 fainter stars.

Unfortunately, a meridian photometer constructed as just described suffers one marked disadvantage: faint stars cannot be measured with an instrument of even moderate size owing to the splitting of the beam from each objective, and to the way in which the light intensity of both stars must be decreased in the procedure of equalizing the intensities of the two images. In order to overcome this disadvantage, and to have an instrument with which the magnitudes of faint stars could be measured, Pickering designed a modified meridian photometer of large aperture. This modified instrument employed a single objective of 12 inches diameter, and made use of an artificial comparison star. The intensity of this artificial star was varied by means of a neutral absorbing wedge placed in the optical train that formed the image of the artificial star. Thus the modified meridian photometer was more like a twelve-inch meridian telescope with a photometer somewhat similar to Zöllner's attached to it. Stars as faint as the thirteenth magnitude could be measured with this instrument, which was completed in 1898, and was used thereafter in the investigation of variable stars, the establishment of standard sequences, and various other programs on faint stars.

During the years from 1886 to 1905 G. Müller and P. Kempf, of the Potsdam Observatory, made use of a modified Zöllner photometer to measure the magnitudes of all stars brighter than magnitude 7.5 on the scale of the *B.D.,* and located north of the celestial equator. The catalog resulting from these measurements, the *Potsdam Durchmusterung,* (*P.D.*) enjoys the reputation of being the most accurate of the more extensive photometric catalogs of the second photometric period. This accuracy was gained not through any innovations in the photometric instruments, but rather through the great care taken in the planning and execution of the program.

Before starting observations on the main photometric program, Müller and Kempf chose 144 standard stars well distributed throughout the sky and ranging in brightness between magntiudes 4.5 and 7.3 and determined for them, on a Pogson Normal Scale, magnitudes of a very high degree of precision. Particularly in observing these standard stars,

but also generally in making the catalog observations, many precautions were taken. Both Müller and Kempf observed each star; each star was observed in four positions with respect to the artificial comparison star, and so forth. Several telescopes were used in the program, but the observations were carefully reduced to the particular photometric system of one telescope. The zero point of the scale of these standards, and thus also of the *P.D.*, was determined by making the average magnitude of the standards agree with the average *B.D.* magnitude (6.02) for the same stars.

The main body of stars to be observed was divided into small groups or zones, each containing 12 stars. Two standard stars, conveniently situated in the sky, were observed before, in the middle of, and after each set of zone observations, and the magnitude scale of the standard stars was in this manner accurately transferred to the main group of stars. Each of the observers, after measuring the magnitude of each star, made a visual estimate of its color. These color estimates were an important part of the literature of the first photometric period on the subject of stellar colors.[6]

The first period of astronomical photometry reached its climax with the publication of the great *Durchmusterungen;* the much shorter second period reached its climax with the publication of the less extensive but more accurate catalogs of Pickering and of Müller and Kempf. The general trend of development during this second period followed quite closely the pattern set by its predecessor. Most of the observers engaged in photometric work were interested in the compilation of catalogs—in the determination of magnitudes for large numbers of stars spread over large areas of the sky. This tendency evolved directly from the habits and points of view of the astronomers of the first period; the introduction of photometers in the second photometric period merely made it possible, in general, to establish more accurate magnitudes and more accurate scales than had been established previously. As the science of astronomy progressed, however, and as new fields were opened and the general outlook of astronomers broadened, some observers became interested in more specialized fields of photometry. Much of this specialized interest became evident only at the end of the major part of the second period, however, or even after the major portion of that period had ended, and this had the effect of extending the second period and causing it to overlap at times even the more active parts of the third period.

[6] It should be mentioned that the *P.D.* has been somewhat extended in scope by Tass and Terkán at Ogyalla. These observers, using two Zöllner photometers and following the same general procedure devised by Müller and Kempf, have determined magnitudes for all stars brighter than magnitude 7.5 and lying in the zone 0° to —10°. While still of a high accuracy, the precision of this extension is less than that of the work carried out at Potsdam.

The Specialized Fields of Photometry

Double Star Photometry. The field of double star photometry was, during the first photometric period, one of the most difficult of all photometric fields because of the great errors to which the human eye and human judgment are subject when two stars (frequently of very different brightness and color) are seen close together. The magnitude estimates of different observers often differed, in such instances, by several magnitudes. The introduction of photometric measuring instruments, however, eliminated many of the difficulties involved, and, in general, made possible more reliable magnitude determinations for double stars than had ever before been available, particularly in those cases where there existed a considerable difference in brightness between the components of the system.

Several photometers were especially designed for work on double stars. At the Harvard College Observatory two photometers of this type were in use. These instruments, although they were attached to a normal equatorial telescope and did not make use of two objectives, were generally similar to the meridian photometer. Each consisted essentially of a double-image prism that was placed between the objective of the telescope and its focal plane, and a Nicol prism located between this double-image prism and the eyepiece, just in front of the latter. Light from each star passing through the first prism was split into two beams, and hence each star was apparently double, the "components" of this "double star" being plane polarized at right angles to each other. The position angle of these "components" could be changed by rotating the double-image prism; their separation could be adjusted by moving the prism along the optical axis of the telescope. Thus a real double star having components AB would appear when viewed through the photometer to be a quadruple star having components Aa and Bb. By adjustment of the double-image prism (motion along optical axis, rotation about optical axis) image a was placed near image B for easy comparison; the Nicol prism was then rotated until a and B were of the same apparent brightness. When so adjusted, the position angle of the Nicol furnished a measure of the magnitude difference of A and B. The precision attained with a set of observations made with these photometers was rather high, the probable error being of the order of 0.1 magnitude.

In more recent years objective gratings constructed of parallel wires or bars have been used in the determination of the magnitude differences of the components of double stars. Successful application of this grating method requires that the observer have available a fairly extensive set of gratings of different constants, say every half-magnitude or possibly every magnitude, and, ideally, also of various dispersions. The use of these gratings is very simple and direct. With the grating of constant nearest the magnitude difference of the components before the

objective, the observer compares the central image of the companion and the first (or possibly higher) order image of the primary and, by eye, estimates in tenths of a magnitude, the difference in brightness of these images. From this estimate and the known grating constant, the desired magnitude difference can be found at once.

It has been suggested that a grating of "variable constant" might be constructed. In using a device of this type the observer would simply adjust the grating until the central image of the secondary and the first order image of the primary were of equal apparent brightness. When this situation obtained, the grating constant would be equal to the desired magnitude difference.

The general method of objective gratings is very convenient, and, if a satisfactory set of gratings is available, quite accurate.

Colorimetry. The study of star colors was in many respects rather neglected during the second period of astronomical photometry, and, in fact, did not become a subject of importance in the field of astronomy until the introduction of photography in the third photometric period. Secchi, well known for his early studies of stellar spectra, determined star colors in 1852-1855 by comparing the stars with lines of some conveniently excited emission spectrum. Other observers, notably B. Kincaid in 1867 and W. H. M. Christie in 1874, suggested means of mixing various colored and white beams of light, the intensities of which could be varied independently, these adjustments being so manipulated that the resulting colored light matched that of the star under consideration. Zöllner, in 1860, included in his polarizing photometer a device for determining the color of a star as well as its brightness. The apparatus for making this color measurement consisted of a quartz plate and an additional Nicol prism that were located in the optical train that formed the image of the artificial star. By adjustment of the Nicol with respect to the quartz plate the color of the light forming the comparison star could be varied, and could be made to match that of the real star, and thus yield a numerical measure of the color of the star. This device never achieved great popularity and was little used.

A very simple and ingenious method of obtaining star colors was proposed by C. Chandler in 1888. Chandler wanted, he wrote,[7] "to convert difference in color between two stars into difference in brightness thus changing the element to be directly observed from a very uncertain to a certain one." He effected this conversion "by means of a colored shade-glass, which, by its selective absorption, [altered] the apparent relative brightness of stars of different colors. Thus a red star which [appeared] equal to a white one, when viewed in the ordinary way, [appeared] fainter than the latter when a blue shade-glass [was] applied to the eyepiece, and brighter when a red shade-glass is used. These differences, which [could] be estimated very precisely by Argelander's

[7] *A. J.*, **8**, 137, 1888.

method, thus [became] measures of the difference of color, of course on an entirely arbitrary scale, depending upon the amount and selective character of the shades employed." This method devised by Chandler is the first application of the principle upon which our modern color index is based.

During the second period of astronomical photometry, two new branches of color photometry developed. The first of these was concerned with the more generalized concept of stellar color which we find in spectrophotometry, the second with the subject of effective wave lengths.

The field of spectrophotometry, in which the goal is to determine for the luminous source under consideration the distribution of light intensity as a function of wave length, was started by Fraunhofer in 1817. Fraunhofer's spectrophotometer, which he used to determine the intensity distribution in the solar spectrum, consisted essentially of a visual slitless spectroscope, in the focal plane of the eyepiece of which was located a small metallic mirror that made an angle of 45° with the line of sight. Light from a standard source entered the spectroscope from the side, and was reflected from this mirror to the eye of the observer. The intensity of this light could be varied by changing the distance of the standard light source, an oil lamp, from the mirror. Spectrophotometric measurements were made with this device by adjusting the relative positions of the mirror and the spectrum until the mirror intercepted a known wave-length range of the spectrum and then finding the proper distance of light source from the mirror such that the intensity of light reflected by the mirror to the eye appeared to be equal to that blocked out from the spectrum by the mirror, as judged from the brightness of the spectrum on either side of the mirror. By examining a series of spectral regions in this manner, the variation of light intensity throughout the spectrum was supposedly determined.

Of the many obvious faults in this first spectrophotometer, the greatest was undoubtedly the lack of match of color of light from the standard lamp and the part of the spectrum being examined. White light or essentially white light was compared with colored light, and it is therefore not surprising that the results obtained by Fraunhofer were not altogether satisfactory. In spite of the poor quality of the results obtained, however, this first spectrophotometer, and the idea behind it represented a considerable advance in the scope of photometry.

During the years following the pioneering work of Fraunhofer, many improvements were made in spectrophotometers. These improvements frequently took the form of more satisfactory sources; the spectrum under consideration was compared region for region with the corresponding parts of the spectrum of some standard source rather than with the total light of some standard lamp. Likewise, improvements were made in the apparatus for varying the intensity of the comparison

source, these improvements following closely the evolution of the ordinary photometer already discussed.

Most of the experiments carried on with these improved spectrophotometers were performed in physical or chemical laboratories. Except for a small amount of spectrophotometric work on the sun, it was not until 1880 that spectrophotometers began to be used in stellar astronomy. In that year H. C. Vogel published spectrophotometric measurements between the wave-length limits 4400A and 6400A for six stars. The instrument with which these measurements were made, a Glan-Vogel spectrophotometer, consisted, fundamentally, of a visual slit spectroscope which was attached to the eye end of a telescope and which had, between the collimator lens and prism, a double-image prism and Nicol as in the Harvard double star photometer. The slit of the spectroscope was divided into halves. Through one of these halves the light of an oil lamp (the standard source) was directed by means of a right-angled prism; through the other half was admitted the light of the star to be studied. Except for the fact that the light from a small spectral range of the source was compared with the light from the star in the same spectral region, the measurements with this spectrophotometer were made in the same manner as they were with the double star photometer.

A more extensive set of spectrophotometric measurements was made by J. Wilsing and J. Graff in 1905, and by J. Wilsing, J. Graff, and W. Munch in 1911 with a Crova type spectrophotometer. This latter instrument was generally similar to the Glan-Vogel spectrophotometer. It differed from it in detail, however, in that the mechanism (two Nicol prisms in line) for varying the intensity of the light beam from the standard source was not connected directly with the spectroscope, but was placed in a section of the light beam outside of that instrument. The light from the standard source was thus varied in intensity before it ever entered the slit of the spectroscope. In the Crova spectrophotometer, therefore, no star light was wasted through double refraction and polarization, and hence much fainter stars could be measured with it than with the Glan-Vogel instrument.

In order to avoid many of the difficulties[8] inherent in spectrophotometry some observers preferred to use a so-called "heterochrome photom-

[8] These difficulties are very numerous. In the numerical reductions allowance must be made for the selective absorption and reflection of the optical system; for the effects of chromatic aberration which causes the various spectral regions to be differently widened perpendicular to the direction of dispersion; it is desirable to reduce the measurements made with a prism as the dispersing agent from a prismatic to a normal scale; trouble is frequently encountered with the undesirable effects of strong absorption lines especially in later type spectra; finally, if a slit is used in the spectrophotometer, the tremors in the atmosphere ("bad seeing") cause the thin, drawn-out line of the spectrum to undergo rapid intensity variations. On the other hand, there are some compensations in spectrophotometry, for one is dealing with essentially monochromatic images, and hence many of the difficulties of ordinary photometry do not enter into the work.

eter" of the type constructed by Ch. Nordmann in 1909. Nordmann's photometer was essentially a compromise between a true spectrophotometer and a total visible radiation photometer of the type devised, for example, by Zöllner or Pickering. In the heterochrome photometer provision was made (a normal Zöllner photometer could be used as the basic instrument to be coverted) for the insertion of various color filters of known transmission properties just in front of the eyepiece. Thus there were made measurements of the intensity of light of a star in a series of spectral ranges, which, while generally broad compared to the ranges measured with a spectrophotometer, were far less broad than the range covered in the ordinary photometric procedure.

Nordmann's photometer, like the true spectrophotometer, was primarily of interest to the astrophysicist in the solution of certain physical problems such as the determination of stellar temperatures, and so forth. Although the field of spectrophotometry is a very important one astrophysically, it is necessarily of much more limited applicability than the general field of total visual radiation photometry inasmuch as we use only a small fraction of the total visible light radiated by the star in each comparison. One is therefore limited in this field to the observation of relatively bright stars.

The second new field which originated during the second photometric period and which stems from the general subject of color photometry, is that of effective wave lengths. The first measurements of what we now term effective wave length appear to have been made in 1897 by G. Comstock during his investigations of atmospheric refraction. Comstock defined the effective wave length of a star, λ_{eff}, as the wave length of the visually brightest part of its spectrum, and measured this quantity for a number of stars. He accomplished this by placing in front of the objective of a visual refractor two parallel rectangular apertures and observing the separations of the visually brightest portions of corresponding diffraction images thus formed. The diffraction images were treated as double stars; the measurements were made with a filar micrometer, the linear separations thereby obtained later being converted to wave-length equivalents. Although these measurements were difficult to make and the mean error of a determination was rather large, Comstock's values of λ_{eff} show an unmistakable trend with the color estimates made by eye or with the spectral classes of the stars.

After the work of Comstock had appeared, further measurements were made by Lau (1906), by Bernewitz (1921), and lastly by Grammatzki (1924), who increased his accuracy over that of his predecessors to a considerable degree by adding to his optical system a small cylindrical lens which spread the light of each image in a direction perpendicular to the direction of dispersion of the grating or slits before the objective.

Variable Star Photometry. Variable stars received a rather consid-

erable amount of attention during the second photometric period and many photometric studies of them were made with the same photometers that have already been discussed. One of the more interesting papers dealing with the application of visual photometers to variable stars is a relatively recent one (1933) by A. Danjon of the Strassbourg Observatory, in which he describes his "Cat's Eye" photometer and the results obtained with it. The "Cat's Eye" photometer is one of a general type first described by W. J. s'Gravesande about 1700 and later developed by Steinheil (1836), Pulfrich (1925), and others. Danjon's apparatus, which was experimental in nature, was built around a small refracting telescope. Situated before the objective were two right-angled prisms, one directly in front of the center of the objective, the other to one side of the telescope. Mechanical arrangement allowed these prisms to be rotated about properly chosen axes to permit two star fields to be superimposed and viewed simultaneously by the observer. One of these fields was seen directly through the outer parts of the objective, the other, located at a moderate angular distance from the first, through the prisms.

Between these prisms was located a "cat's eye" diaphragm[9] of square aperture constructed of two metal plates, the ends of which were cut in rectangular V form. As the plates were slid together, a square aperture of constantly decreasing size was formed, and the apparent brightness of the stars in the field seen through the prisms could thus be varied, this controllable variation being used for comparing the brightness of stars situated not too far apart in the sky.

The intensity of starlight viewed through the diaphragm varied as the area of the aperture (or as the diagonal squared) of the diaphragm. In terms of familiar magnitude units

$$\Delta m = c - 5.0 \log s,$$

where Δm represents the magnitude difference between the star image as seen directly through the telescope and through the prisms and telescope, when the diagonal of the diaphragm is s cm long. The constant c represents the value of Δm when $s = 1$ cm. The formula as given is, unfortunately, not completely rigorous. As written it does not take into account a small variation in c which depends upon the cosine of the angular separation of the stars being compared, or a small departure from a true log s relationship owing to the variation of absorption of light over the surface of that part of the objective covered by the prism. Both of these errors are small and may be determined and corrected. The error, which might be anticipated, owing to a difference in the diffraction patterns of the images being compared appears to be very small.[10]

[9] Also called an Aubert diaphragm. It serves the same purpose as an iris diaphragm.

[10] In making this statement it is assumed, of course, that the brightness range over which comparisons are made is not extreme.

The accuracy that can be achieved with this type of photometer is, according to Danjon and others, very high. The uncertainty in the determination of a Δm appears to be about $0^m.01$, and it would certainly seem that a complete investigation of this very simple type of photometer by some of the present observers having available mainly smaller visual instruments would probably be well repaid.

Surface Photometry. Another new field of research opened to astronomers by the introduction of photometric measuring devices was that of the measurement of surface brightness—surface brightness of the sun, the moon, the planets and their satellites, the comets, nebulae, clusters, and finally, of the sky itself.[11] The observations of these various objects, it can be said briefly, were, in the main, made with instruments which resembled, and which were in general adaptations of, those photometers already discussed. The adaptations were frequently made simply by changing the point-comparison-image forming system into one which illuminated a comparison surface. All the methods that were used for varying light intensity in point photometers were used in surface photometer—Nicol prisms, extinction wedges, diaphragms, inverse square law of diminution of illumination, and so forth—and, generally speaking, an advance in the construction and accuracy attainable with one type of photometer (point or surface) was accompanied by a similar advance in the other type.

The Mathematical Definition of Stellar Magnitude. The concept of stellar magnitude has been used very frequently in this discussion, but so far no real definition of that term has been given. One of the important advances of the second photometric period was the establishment of just such a definition. The first stellar magnitudes (in the present sense of the term) came from the *Almagest* of Claudius Ptolemy some 1800 years ago. Ptolemy, it will be remembered, divided all the stars visible to the unaided eye into six[12] classes called magnitudes. The brightest stars in the sky were said to be first magnitude stars; those just comfortably visible on a dark moonless night, sixth magnitude stars. Occasionally, Ptolemy further subdivided his brightness intervals by using descriptive terms to place stars between his whole magnitude steps. Thus a star whose brightness Ptolemy considered to be between the second and third magnitudes might be designated "2 more" or "3 less" depending on whether it was more nearly equal in brightness to a second magnitude star or a third magnitude star.

Thus, originally, magnitude referred to the intensity of the visual

[11] Primarily the night sky. It should also be mentioned that in connection with the photometry of the moon, planets, and other bodies of the solar system, a considerable amount of theoretical work was done on albedo, light variation with phase angle, and so forth, during the second photometric period.

[12] H. Osthoff suggests that Ptolemy, in choosing six, was influenced by the mysticism of Babylon, where six was regarded as a sacred number. The choice is probably connected with our sexagesimal time and angle measuring systems.

sensation produced by a luminous object, a star, and Ptolemy's magnitudes were nothing more than estimates of visual sensation. In 1859, however, Fechner announced his famous psycho-physical law and gave a rational statement of the connection between the subjective experience of brightness and objective physical cause.

The difference in the responses of the retina produced by two stars differing only in brightness, asserted Fechner, did not depend upon the actual intensities of the light from the stars, but only upon the percentage change in the intensities. From this statement follows almost at once the familiar Fechner equation

$$\log (I_m/I_{m+1}) = \log \rho$$

or

$$I_m = \rho\, I_{m+1}$$

where I_m represents the intensity of light received from a star of magnitude m, I_{m+1} the light from a star identical with the previous star save that it is of magnitude $m + 1$, and ρ a constant to be determined. Written in still another and perhaps more useful form, this equation becomes

$$m_1 - m_2 = (1/\log \rho) \log (I_2/I_1)$$

where m_1 and m_2 represent the magnitudes of two stars designated by the subscripts 1 and 2, and I_1 and I_2 represent the light intensities received from those respective stars. The quantity ρ is again a constant to be determined.

We know today that Fechner's Law is not strictly correct, and that in fact the difference in the responses of the retina produced by two luminous sources of a given intensity ratio varies somewhat with the intensities of those sources. The form of Fechner's Law, however, is found in all our present photometry; the equation as stated originally by Fechner, in spite of its error, determined the course of subsequent events in astronomical photometry.

From the measurements of stellar brightness made during the second photometric period it was possible to determine Fechner's constant ρ. In 1836 C. A. Steinheil, working with his prism-photometer, found that the magnitudes which had been assigned to the stars by former observers were approximately proportional to 2.24 times the logarithm of his measured light intensities. Thus Steinheil, in a sense, anticipated the work of Fechner by more than 20 years; but it required the fundamental investigation of Fechner to give the relationship which bears his name the position that insured its application. From the work of S. Stampfer (1851), M. J. Johnson (1853), N. Pogson (1856, 1857), G. Fechner (1859), C. S. Pierce (1879), and others, values of $\log \rho$ similar to that of Steinheil have been found. In 1879 E. C. Pickering adopted the value $\log \rho = 0.400$ ($\rho = 2.512$) for the extensive series of photometric observations then in progress at the Harvard College Observatory. This

particular value of log ρ, which had been suggested by Pogson in 1856, was used quite generally by astronomers after its adoption by Pickering, and was finally adopted by International agreement as the standard scale value to be used in all photometry. Photometric scales for which log $\rho = 0.400$ have become known as Pogson Normal Scales.

If, having adopted a value for ρ, we now arbitrarily set the magnitude for one star or a group of stars (that is, if we choose the zero point of our magnitude scale) we may, then, with the constant ρ, extend the system in either direction towards brighter or fainter stars. The zero point[13] of the present International Standards, which form the North Polar Sequence, and which we shall discuss in detail later, was chosen in such a way that magnitudes of white stars (the A0 stars) between magnitudes 5.5 and 6.5 are, on the average, in agreement with the corresponsing photometric magnitudes of the Polar Sequence established at the Harvard College Observatory. The Harvard Polar Sequence was established by means of extended series of measurements made with the meridian photometers. The zero point of the Harvard system was determined by making the average magnitude (approximately 4.0) of 100 northern Harvard standard stars agree with the average magnitude assigned to those same stars by Argelander. Argelander's scale and zero point were based on the historical scales of the past, and thus, eventually, our zero point can be traced back essentially to Ptolemy!

The Precision Attained by the Observers of the First and Second Periods. The question of the degree of precision attained by the observers of the first and second photometric periods is one of considerable interest. An estimate of this precision may be obtained most readily by making a detailed comparison between the older catalogs in which we are interested and modern ones which are of known precision and which are founded on contemporary standard magnitude scales. Such a comparison is generally a task involving a considerable amount of labor owing to the large number of photometric effects involved in magnitude determinations. Unfortunately, in our comparisons, it will be necessary to omit a consideration of most of these effects, the most common of which are listed below without further discussion.

i *The color equation and Purkinje effect.* The color sensitivity of the retina varies from observer to observer. Thus even though two observers agree in their magnitude estimates for stars of one color, they will not necessarily agree in their estimates for stars of a different color. This so-called "color equation," the error in magnitude estimate caused by color, is further complicated by the Purkinje effect. Purkinje found that when red and blue surfaces apparently equally bright at some moderate level of illumination are both gradually reduced in in-

[13] The zero point to be given for the North Polar Sequence is that of both the photographic and photovisual scales. We are discussing at present, however, only the visual (or photovisual) scale.

tensity in such a way that they retain the same actual ratio of intensity at all times, the blue surface remains visible for a longer time than the red one, that is, when both surfaces are faint, the blue one appears brighter than the red one, although at higher levels of illumination they appeared equally bright.[14] Thus it is highly likely that the color equation mentioned above will be a function of the apparent magnitudes of the stars.

ii *The background effect.* Magnitude estimates generally depend to a considerable degree upon the intensity of the sky background against which the star is seen. The magnitude estimated for a star viewed on a moonlight night or in a rich Milky Way field will, in general, differ noticeably from the magnitude which would be assigned to the same star if it were observed on a moonless night, or in a barren star field. The importance of the background effect varies from observer to observer.

iii *The position error.* The sensitivity of the retina varies from point to point over its surface. Thus, results of a comparison of the brightnesses of any two stars depend upon the actual positions of the star images formed on the retina by the lens of the eye. Two kinds of error of this type can be distinguished: one which depends upon the apparent angular distance between the stars; one which depends upon the position angle of the line joining the two stars relative to the line joining the observer's eyes.

iv *The decimal error.* This is a purely psychological error. Some observers have certain decimal preferences. They tend, for example, to crowd their estimates into classes ending in the decimals 2, 5, or 7 (or some other such series) rather than spread them evenly over all decimal classes.

v *The extinction correction.* Our atmosphere absorbs light, and therefore stars observed low in the sky will be estimated systematically too faint relative to stars higher in the sky if proper allowance is not made for their varying light-paths through the atmosphere.

vi *Seasonal or other variations* which cause the magnitude scale to vary from one part of the sky to another. The effect of practice or experience may also be a factor in this type of variation.

In addition to keeping these various photometric effects in mind when comparing two photometric catalogs, it is necessary to distinguish between two types of accuracy: external accuracy, or accuracy of scale, and internal accuracy, or accuracy of a catalog magnitude on the catalog scale.

[14] Gallisot, in 1921, studied this effect of actual intensity upon color equation for stars (point images) and found just the contrary to be the case. Gallisot found that a red star appeared brighter than a blue one if both were faint although they appeared equally bright if both were brighter. Most photometric catalogs confirm the Purkinje effect however.

In Table I will be found a comparison between the magnitude scales established by some of the observers of the first photometric period, and the modern magnitude scale, a Pogson Normal Scale.

TABLE I

COMPARISON OF OLD MAGNITUDE SCALES WITH MODERN SCALE

M	Ptolemy	al-Sûfi	Tycho Brahe	Argelander	Heis	Gould
	m	m	m	m	m	m
1.0	1.0	0.9	0.9	0.6	0.6	0.8
	1.4	1.2	1.5	1.7	1.7	1.5
2.0	2.4	2.1	2.4	2.3	2.3	2.3
	1.2	1.2	1.1	1.1	0.9	1.0
3.0	3.6	3.3	3.5	3.4	3.4	3.3
	0.9	1.1	1.2	0.9	0.9	0.9
4.0	4.5	4.4	4.3	4.3	4.3	4.2
	0.5	0.5	0.5	0.8	0.8	0.8
5.0	5.0	4.9	4.8	5.1	5.1	5.0
	0.3	0.4	0.4	0.9	1.0	0.9
6.0	5.3	5.3	5.2	6.0	6.1	5.9

The first column of the table headed M, gives the magnitude for the observer under discussion; the entries in the body of the table give the corresponding values in terms of the modern magnitude scale. For example, the modern value corresponding to Ptolemy's $1^M.0$ is $1^m.0$, the modern value corresponding to Ptolemy's $2^M.0$ is $2^m.4$; and so forth. The small intermediate numbers in the body of the table are the differences between consecutive magnitude values, and give information in regard to the true interval in light intensity between consecutive magnitude values assigned by the observers listed.

It is immediately evident that the modern and old magnitude scales are not in close agreement. Among the old scales, however, there are some very consistent tendencies. The scales established before the time of Argelander are all very strongly influenced by Ptolemy's work; those derived after the time of Argelander are strongly influenced by Argelander's work. There is a very strong tendency for all observers to compress their scales for the brighter stars (they include too great a magnitude interval between consecutive magnitudes); and to extend them for fainter stars. Using the average of the scales of Ptolemy, al-Sûfi, and Tycho Brahe, a first magnitude star is 3.53 times as bright as a second magnitude star; a fifth magnitude star only 1.41 times as bright as a sixth magnitude star. Thus these scales are far from uniform. The later observers, Argelander, Heis, and Gould, for example, have much more uniform scales, as is evident from an examination of the table.

The scales of the *B.D.*, *S.D.*, and *C.D.* are more difficult to discuss than those of the *Uranometriae* since the scales of the *Durchmusterungen* are inhomogeneous and vary from one part of the sky to another. In general, the scales of the *B.D.* and *S.D.* are compressed for the brighter stars and extended for the fainter ones, especially those fainter

than the sixth magnitude. The scale of the *C.D.* is generally linear, but the constant log ρ is more nearly 0.32 than 0.40.

A measure of internal accuracy in the form of the mean error and information as to fractional part of a magnitude to which various observers recorded their results are listed in Table II.

TABLE II

TABLE OF MEAN ERRORS AND SMALLEST CATALOG UNITS

Observer	Unit	Mean Error
		m
Ptolemy	1/3M	±0.47
al-Súfi	1/3	0.38
Tycho Brahe	1/3	0.54
W. Herschel	0.1	0.11
J. Herschel	0.1	0.07
Argelander	1/3	0.27
Heis	1/3	0.27
Gould	<0.1	0.15
Argelander-Schonfeld (*B.D., S.D.*)	varies	0.22
Thome (*C.D.*)	1/4	±0.3*

*Average value. Actual value varies from one part of the sky to another.

The introduction of photometric measuring instruments brought about an immediate increase in both accuracy of scale determination and the accuracy of individual magnitude determination. In Table III for which the arrangement is as for Table I, the scales established by three observers of the second photometric period are compared with the modern scale.

TABLE III

COMPARISON OF SECOND PERIOD SCALES WITH MODERN SCALE

M	Oxford		Harvard		Potsdam	
					m	
1.0					0.74	
		m				1.00
2.0	2.18				1.74	
		0.96				1.00
3.0	3.14				2.74	
		0.92	m			1.00
4.0	4.06		3.92		3.74	
		0.97		1.02		1.00
5.0	5.03		4.94		4.74	
		(1.17)		1.05		1.03
6.0	(6.2)		5.99		5.77	
				1.07		1.03
7.0			7.06		6.80	
				1.05		
8.0			8.14			
				1.08		
9.0			9.24			
				1.10		
10.0			10.25			
				1.01		
11.0			11.16			
				0.90		
12.0			12.06			

Table IV exhibits the internal accuracy achieved by some of the observers of the second photometric period.

TABLE IV

TABLE OF MEAN ERRORS: SECOND PERIOD

Catalog or Observer	Year	Mean Error
		m
Sidel and Leonhard	1856	±0.051
Zöllner	1859-1860	0.04
Harvard	1879-1902	0.08
Oxford (Pritchard)*	1881-1885	0.19
Potsdam (Müller and Kempf)	1886-1905	±0.052

*The mean error quoted for Pritchard is that derived from a comparison of his magnitudes with those of others. If Pritchard's values are compared among themselves the mean error is approximately ±0m08. The difference between this value and the one quoted is due to the tendency for an observer to call a star brighter than it actually is when observing with a wedge photometer.

The advances in astronomical photometry made possible by the introduction of photometric instruments were many; the increase in accuracy in both internal and external accuracy achieved through use of the instruments of the second period is readily evident from an inspection of the above tables.

The second photometric period itself, considered historically, appears as a divided period. By 1900 most of the work of the period in what might be termed the main branch of photometry, the determination of magnitudes for the stars in general, had nearly come to a close. The work done in the field of visual photometry after the start of the present century was, in the main, work in specialized fields such as double-star photometry, variable-star photometry, spectrophotometry, and so forth. The reason for this rather sharp division is found in the growing importance at the time of the division of an entirely new method or process of observing and measuring radiant energy. It would not be an exaggeration to say that this new process of observing light—the photographic process—had not only brought the second period of astronomical photometry essentially to an end by 1900, but had by that time changed the whole course of astronomy and has, in a large part, made possible the tremendous development of astronomy that has taken place during the last half century.

(To be continued)

Timing Devices used at Herne Bay*

By E. F. JEFFRIES**

ABSTRACT

A description of the two timing systems used at Herne Bay, England, on the recent world speed record attempt by two Gloster Meteors (British designed and built jet-propelled aircraft). The attempt was made over a 3 kilometre surveyed course,—marked by a sighting post at each end. Two runs were measured in each direction, and the average speed of the four runs—606 miles per hour—set up a new world record.

It was absolutely essential to devise a scheme for timing the flights that offered the very smallest margin of error. To reduce the error still further, it was decided to use two methods of timing—as a check against each other. They were both photographic in principle. One depended on a cinecamera, the other on a still camera.

The systems of timing dials used with both methods were controlled in the same way as the ordinary domestic electric clock, that is, by the frequency of the current and not by the voltage. Obviously, therefore, this frequency had to be very accurately controlled in order to meet the international requirement for a time accuracy of at least one in 360,000.

The National Physical Laboratory at Teddington (just outside London) has, as part of its standardization equipment, a quartz-crystal-controlled oscillator operating at 100,000 cycles a second, which can be stepped down in frequency by a series of multi-vibrator units for various requirements. The stability of this frequency is one part in a hundred million. That is equivalent to an error of one second in three years.

The National Physical Laboratory sent a signal to us at Herne Bay from this oscillator, at 200 cycles a second. It was sent both by radio and by Post Office land line. The land line proved to be more reliable and we used that, keeping the radio as a stand-by.

When we got it, we passed the signal through a 200 cycle tuning fork which was kept in a constant temperature chamber. The function of the tuning fork was to carry over during short term disturbances of the input signal, such as static. Pickoff coils were mounted on the other arm of the fork and the signal passed to both huts and amplified to the level required by the timing apparatus.

We had a hut at each end of the course, and the signal was transmitted by land line from the master hut to the hut at the other end of the

*Text of a British Broadcasting Corporation program.

**Senior Technical Officer of the Royal Aircraft Establishment who was responsible for the speed timing equipment and was an official timekeeper.

course. As a simple visual check on the frequency (just as you have a stroboscope on a gramophone) we installed double beam oscilloscopes in each hut and connected them permanently into the system.

I have mentioned that we used two methods of timing. The first consisted of two high-speed cinecameras used in conjunction with the timing dials, phonic-motor-driven tuning dials. The phonic motor itself was driven by the amplified signal from the pick-off coils, of the tuning fork. By their nature, these motors must keep in step with the frequency or stop altogether. From this it followed that the motors at both ends of the course ran in step.

The cinecameras, which operated at approximately 150 frames a second, were driven by separate electric motors which were started individually as the aircraft approached each sighting post. The dials, which showed minutes, seconds, and hundredths of a second, were simultaneously photographed with the sighting post when the motors were started. The dials at both ends of the course were started together by a push button in the master hut some minutes before the Meteor was due to cross the sighting post.

To work out the speed of the flight the film had to be processed and a series of consecutive pictures of the aircraft had to be plotted on a graph against the instantaneous dial readings. The precise instant at which the aircraft passed each sighting post was then taken from the graph. The difference in the time readings on the films from either end of the course was the time taken to travel the three kilometres.

Before the aircraft appeared, both sets of timing dials were set to zero, and photographed while stationary. At the end of the series of timed runs, the dials were simultaneously stopped and photographed again. We did this as a further check that the dials had started simultaneously.

The National Physical Laboratory checked that the maximum error which could have been introduced by this system was one five-hundredth of a second. The average error was one-thousandth of a second. The overall accuracy (and this included every conceivable source of error) was one part in five thousand, roughly one-tenth of a mile an hour at 600 miles an hour.

In the second timing method two still-picture aircraft-cameras were used. (They were type F24 Single Shot.) They were placed on the roofs of the huts, directly over the cinecameras used in the first method. These still cameras were operated in conjunction with a Chronograph Recorder at one end of the course.

As the aircraft passed the post the operator released the shutter and took a photograph of it. Automatically a mark was made on a paper strip being fed through the Chronograph Recorder. On this paper strip timing marks (showing hundredths of a second and tenths of a second) were also being registered. These were controlled by the N.P.L.'s fre-

quency signal. The time between the two exposures was calculated by counting the number of tenths and hundredths of a second between the marks made by the two cameras.

This time was not necessarily the time for the aircraft to cover the measured three kilometres, owing to the personal error of the operators of the cameras. They couldn't possibly guarantee to operate the shutter at the instant the aircraft was in line with the sighting post. After all, 600 miles an hour is nearly 300 yard a second. After the photographs were processed this error in distance was measured on the prints and the appropriate correction made. The correct speed was then calculated.

We could give an approximate snap answer by the Chronograph method, if we ignored the photographs and read the times direct off the paper strip. This, of course, did not take into account the necessary slight corrections. And there was also the possibility of making a mistake in counting the time markings on the strip—because we were doing it in the hurry of the moment between two runs, without checking and with the noise of the loud speakers and the general bustle and din of the occasion to distract us.

As a matter of fact, two miscalculations were made during the practice runs, and, to avoid this sort of thing happening again, the counting for these snap results in future trials will only be done after the end of the four runs. The snap answer may, of course, be wrong either way by as much as twenty miles an hour, due to the aircraft not being in line with the post when the photograph is taken. But on the average, even the snap answer was correct to within five miles an hour.

To get the final accurate answer by the second—Chronograph—method, you had to wait five or six hours until the film had been processed, corrections and calculations made, checked, and rechecked. But when all this was done, the result gave the speed of the aircraft to within one part in 5,000. This accuracy was borne out by comparisons which we made between the two methods. The disagreement never exceeded a quarter of a mile an hour.

The Glassy Crust of the Moon

By H. PERCY WILKINS, F.R.A.S.

SUMMARY

This paper advances a new theory of the tint and other variations exhibited by many lunar formations ascribing the cause to the lunar crust's being largely composed of volcanic glass it containing cavities filled with gas or liquid. The solar heat engenders movements which over large areas is the cause of the observed changes.

Until the advent of the present century the moon was considered and described as a sterile, arid waste its surface diversified by vast extinct volcanoes, a dead and silent expanse devoid of the slightest shred of atmosphere or a trace of water. In accordance with the kinetic theory it was held to be a changeless world, a planet where nothing happened and nothing could happen save the remote possibility of the crumbling of some particularly steep crater-wall owing to the supposed great variations in temperature or the ever present danger of meteoritic impact.

Modern selenography, however, has shown that things *do* happen on the moon despite the apparent absence of atmosphere and that several areas where marked variations are continually in progress exist on the "changeless" lunar surface. Moreover the changes during any particular lunation are not necessarily repeated during the succeeding one, neither do they depend solely upon the altitude of the sun. These regions of change are significantly enough comprised within a zone bordering the equatorial regions where the maximum temperatures are experienced and always in low lying localities or depressions. They are areas of change on the static surface, oases in the midst of the prevailing lunar deserts, interesting regions where strange dusky spots appear growing and spreading over the surrounding surface, sometimes in one direction sometimes in another, independently of the existing libration or the time elapsed since sunrise. Such areas are found in connection with Grimaldi, Eratsothenes, Julius Caesar, and other ringed enclosures.

Although the existence of these regions can be detected by casual observation and comparatively small instruments, detailed study with a view to detecting their real nature requires favorable atmospheric conditions and moderate apertures. Critical observation reveals that the surface in these places is covered with exceedingly minute asperities presenting a kind of granulated structure; minute craterlets or pits are invariably present frequently connected by delicate clefts like beads on a thread. Occasionally, as in Alphonsus, both craterlets and clefts attain considerable proportions but this is altogether exceptional and, in general, the most favorable circumstances are required for their detection.

The variable spots may be classified under three headings: (a) those which can be seen at all times varying in intensity or size during the lunation; (b) those which appear where previously there was no spot; (c) those which, while normally visible, are occasionally obscured as though by some material of a temporary nature which for a time conceals the true surface. The first class includes the well-known dusky patches within Scheckard, Riccioli, and Julius Caesar, all variable in intensity and area. Example of the second will be found in Eratosthenes and Stöfler, while the best known example of the third type is the floor of Plato. Variable light as well as dark spots of each grouping have also attracted attention.

The gradual darkening of certain areas, the spots grouped under (a) for example, as the solar altitude increases is largely, though not entirely, due to contrast owing to the increased brilliancy of the surroundings as both shadow and shade in the neighborhood disappear, but this is inadequate for classes (b) and (c). Here we have an actual alteration of the surface due either to some dark material drawn out of or deposited upon the neighboring rock or to the gradual dissipation of some light coloured substance overlying the true and normally dark surface. It is either the covering over of the light surface by some dark material or the clearing away from the dark surface of some already existing light coloured obscuration.

Up to the present the majority of observers, including the late Professor W. H. Pickering, have assumed that the variations have been due to the evolution of some dark material considered by Professor Pickering to be vegetation, but a careful consideration of the actual appearances favours the idea that the striking changes are due to the removal of some light substance. The dark interiors of Grimaldi and Julius Caesar look like detached portions of the not far removed lunar maria while a large part of the southern hemisphere exhibits near full a greyish appearance as though the original surface of a dark character had been subsequently overlaid by a lighter translucent material through the thinner portions of which the darker foundation can be faintly detected. Where this light material is thicker or denser than usual are knots or streaks of outstanding brilliancy. This appearance promoted the glacial theory, the encasing of the rocky crust in a sheet of ice, but a fatal objection to the idea that lunar formations are composed of ice is their permanence. Slow though its effects might be, glacial flow would inevitably level any ice mountains bringing all to a common level.

The writer believes that the absence of appreciable atmosphere coupled with the low gravitational attraction prevailing at the surface not only greatly favoured the production of vast volcanic craters but of necessity compelled much of the material ejected to be of a light and somewhat special texture. It is highly probable that the lunar surface material consists almost entirely of glass, volcanic glass somewhat like but probably considerably lighter than the "Peles Hair" so abundantly produced at the Hawaiian crater of Kirauea. Where the craters are most crowded might be expected the greatest quantities of glass and this is precisely what is found. The southern hemisphere is the most mountainous and, in general, presents the translucent appearance mentioned.

This appearance is not confined to the southern hemisphere but is characteristic of all parts except the "seas" or maria which seem to represent the original surface doubtless overlaid with a layer of volcanic sand and meteoric dust. An example of the manner in which a plain was subsequently covered by successive layers of glassy material is found in the region between the maria Crisium and Tranquilitatis. The

Palus Somnii was originally a portion of the latter plain and was, in its turn, partially overlapped by another sheet which thickens on the west into the southern highlands of the mare Crisium.

This volcanic glass was doubtless much distended by gas and of a spongy nature full of gas or liquid-filled cavities beneath the surface. It is possible that the solar heat generates currents by agitation of the gas molecules or thawing of the solidified liquid and this may be an explanation of the variations noted in many portions. Many of the appearances presented by the light-streaks find a plausible explanation if they are assumed to be composed of glass the individual masses of which are of a spherical shape and thus symmetrical to the observer irrespective of the varying illumination and libration. A dark surface covered by a thin layer of cavity-filled, translucent volcanic glass, the contents of which solidify during the lunar night and clear under the influence of the heat of the lunar day, would naturally appear best defined under high illumination when the obscuring material was most transparent. On this theory the moon exhibits "Brownian Movements" on a truly impressive scale.

Thus the observed variations are due not to the actual emission of gas but to the movement of gas and liquid confined within a thin shell of volcanic glass. Clefts would here and there place this sub-lunarian gas and liquid into direct access with the surface so that from the crevasses occasional clouds might be expected to make their appearance. This is precisely what happens. The external temporary white spots of a transient cloud-like nature are always found to make their appearance in the immediate neighborhood of clefts, Schickard for example. On the earth glassy lavas often exhibit a cellular structure containing liquid water or oil and are occasionally filled with carbon dioxide which passes into gas at a temperature of 86° F.

Grimaldi, on the other hand, has a dark interior slightly variable in tint containing patches of a darker hue which vary in extent during the lunation and may be due to the growth of some low form of vegetation, possibly of a fungoid type.

The idea here expressed that much of the lunar crust is composed of a light, spongy glass through the semi-transparent skin of which the movement of confined gas and liquid engendered by temperature variations caused the tint and size variations observed is submitted for the consideration of all interested in the elucidation of the mystery of the moon.

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Denison Olmsted an Early American Astronomer

By THEODORE R. TREADWELL

More than a century has passed since the sciences became firmly established in American colleges as essential subjects, no doubt secondary to the humanities at first, but gradually receiving recognition in the academic world as new discoveries were made, and the benefits of their practical application to material progress became evident. Astronomy, usually regarded as the oldest science, stimulated by the discoveries of the Herschels and others, early received recognition in American institutions. According to modern standards the textbooks of a century ago were crude and often erroneous. In many the theories promulgated have been discarded as untenable in the light of subsequent discoveries. Denison Olmsted, the subject of this article, was primarily a teacher and textbook author, and his works, written with meticulous regard for accuracy and completeness as far as the facts were known, became standards and models for his day and generation. As a theorizer he was not so successful, but his never flagging interest and his great ability to communicate ideas gave him an eminent position in scientific circles of his times.

Denison Olmstead was born in East Hartford, Connecticut, June 18, 1791. His father, Nathaniel Olmsted, a descendent of one of the first settlers of the colony, died when Denison was in his infancy. Subsequently his mother remarried and the family removed to Farmington, Connecticut, when the boy was about nine years of age. At that time his mother, not satisfied with the influence of his step-father on the boy, secured a place for him in the home of Governor Treadwell, "to do such chores as a boy could do for his board." He attended the district school for some years and the Governor taught him to cipher—arithmetic not then being taught in the common schools. "In after life Professor Olmsted ever cherished the memory of the Governor with the deepest affection and gratitude, and at a later period embodied his estimate of his benefactor in an elaborate memoir published in the *American Quarcrly Register* for 1943" (President Woolsey).

At sixteen, when he had been for some time employed in a country store, of which one of the sons of Governor Treadwell was a proprietor, he made up his mind to obtain a liberal education and prepared for college at the James Morris School at Litchfield South Farms, and also studied under the tutelage of the Reverend Noah Porter, pastor of the church in Farmington. He entered Yale in 1809. Dr. Dwight was then in the zenith of his reputation and power and exerted a strong influence on his character. At Olmsted's graduation in 1813 he took the rank of "orator," an honor given to only ten in his class of seventy. This year

he obtained the principalship of the Union School at New London, a private school for boys, but returned to Yale in 1815 as tutor, and to study theology under Dr. Dwight. However, on the death of Dr. Dwight about a year later, he decided to continue in educational work. His oration on taking his Master's degree in 1816 was "On the State of Education in Connecticut," in which he outlined a plan, original with himself, of what he termed, "a seminary for school masters," an idea which before his death in 1859 was happily realized in the establishment of Normal Schools.

In 1817 Olmsted was appointed to the Chair of Chemistry in the University of North Carolina. Before assuming his duties there he spent a year in preparation under the private instruction of Professor Silliman at Yale. His work at Chapel Hill included not only chemistry but also geology and mineralogy. At this time he offered to make, for the State, a survey of the geological and mineral resources, a gratuitous offer which was first refused by the Board of Internal Improvement, but later accepted by the State Board of Agriculture. A modest appropriation was made for his expenses. The Report was published in two parts in 1824 and 1825, in all filling about 140 closely printed pages. It was undoubtedly of great benefit, not only to the state, but to the country generally, since it afforded a stimulus for similar enterprises in other states.

In 1825 he returned to Yale as Professor of Mathematics and Natural Philosophy to succeed Professor Dutton, "who in turn had succeeded the lamented Alexander Fisher, Professor Olmsted's classmate and intimate friend, whose brief but brilliant mathematical career was so sadly terminated by shipwreck of the "Albion" off the coast of Ireland in 1822 when on his way to Europe for the purpose of study" (Woolsey). Although, as he himself was well aware, lacking special preparation in higher mathematics and some of the abstruse branches of physics, he applied himself with great zeal to his new duties and became a successful instructor. However, in 1835, at his expressed desire, the department of mathematics was made a separate chair from Natural Philosophy and Astronomy with Professor Olmsted continuing in the latter.

Throughout his career, his life was saddened by tragic bereavement. Of his seven children by his first wife only two survived him. Between the years of 1844 and 1852 four sons, graduates of Yale, giving promise of great ability, succumbed to the dread scourge of consumption, two of them in one year, 1846. Three children by his second wife survived him.

Lack of an observatory and adequate equipment at Yale was a great handicap, but several years before the Harvard Observatory was established, with the great 15-inch telescope under the direction of William Cranch Bond, Yale had obtained a small telescope from England in

1830, at that time considered "the best in the country." Badly handicapped by a wretched location and lack of funds for suitable housing, this instrument was used chiefly for general observations by Professor Olmsted's students. While there were no funds or equipment available for systematic research, this instrument became in the hands of his talented pupil, Ebenezer Porter Mason,* a definite means of astronomical research. Yale can therefore lay claim to establishing the first *permanent* observatory in America. Olmsted's contributions to science were mainly in the teaching and dissemination of scientific knowledge rather than in the field of original research. In this field he was preeminently successful through his numerous textbooks and frequent contribution to the scientific journals of the day. Among his works may be noted the following:

Thoughts on the Clerical Profession. 1817

Students' Commonplace Book. 1828

Introduction to Natural Philosophy, 2 vols. 1831

Compendium of Natural Philosophy. 1832

Introduction to Astronomy. 1839

Compendium of Astronomy. 1841

Letters on Astronomy Addressed to a Lady. 1841

Rudiments of Natural Philosophy. 1844

In addition to these textbooks he contributed many articles on current science to the *American Journal of Science,* and occasional papers of a more general nature to the *New Englander.* His meteorological studies brought the conclusion "that ocean gales are progressive whirlwinds"—still good as a generalization, but his assumed causes of these cyclonic disturbances are not now accepted. He observed the spectacular meteor shower of November 13, 1833, and identified the radiant point in Leo, inferring the cosmic nature of meteors from this and other observations. In 1835 Olmsted and Loomis reported the return of Halley's comet many weeks before it had been seen in Europe. This discovery gave an impetus to the establishment of better observatories although it did not immediately bear fruit at Yale. He desired to have two sections of astronomy at Yale, one for students in general descriptive astronomy, and the other for advanced research with precision instruments. This was not realized in his time because the country was not then ready to supply the funds necessary for this development.

Many editions of Olmsted's texts were printed, especially the "Introduction to Astronomy" which had forty to fifty printings, requiring numerous revisions for the many editions. In all over 200,000 copies were printed. It is not surprising that new editions were necessary since discoveries were going on apace during his lifetime. When the first

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edition was published in 1839, Bessel's measurement of the parallax of 61 Cygni was too late to be included, the significance of solar and stellar spectra was still unknown, Neptune had not been discovered, and the first determination of the velocity of light was not made until 1849. These and other discoveries of the early years were followed closely by Olmsted and incorporated in his text as soon as possible. He was an assiduous reader of the authorities of the day and statements in the text are referred to the sources in numerous footnotes, evidence of the great scope of his reading and the great effort he made to keep his work correct and up to date. The edition of 1841 introduced a "Supplement on Practical Astronomy" by his young protégé, E. P. Mason, a valuable and authoritative treatise on the use of astronomical instruments, methods of calculating eclipses, methods of determining latitude and longitude, and various other practical subjects. This "Supplement" appeared for many years and doubtless had a tremendous influence on teaching methods of exact measurement. In the latest edition at hand, revised by Professor E. S. Snell of Amherst in 1874 (third stereotype printing of this revision) the "Supplement" by Mason is omitted, while the newly added Appendix includes only a few paragraphs on the spectroscopic determination of the constitution of the sun and stars, and radial velocities as revealed by the Doppler effect. Olmsted emphasized the solar system because the investigation of stars had not advanced very far, especially in the field of astro-physics. For example, we find in the 1854 edition that the first 274 pages deal with the solar system and earth problems, while Part III, "On the fixed stars and Systems of the World" is covered in 45 pages. Likewise Snell's 1874 edition devotes even a smaller proportion to the stars.

Olmsted's writings reflect his religious outlook by frequent references to the "divine plan" as revealed by the order in the solar system, and occasional paragraphs are devoted to theological speculations. Speaking of the stars as suns he argues: "If they are suns, and if they exert no important agencies on our world, but are bodies evidently adapted to the same purpose as our sun, then it is as rational to suppose they were made to give light and heat as that the eye was made for seeing and the ear for hearing. It is obvious to inquire next, to what they dispense these gifts if not to planetary worlds; and why to planetary worlds if not to percipient beings? We are thus led almost inevitably to the idea of a 'Plurality of Worlds'; and the conclusion is forced upon us that the spot which the Creator has assigned to us is but a humble province of his boundless empire."

Professor Olmsted died May 13, 1859, at the age of sixty-eight, after thirty-four years of continuous service at Yale. Memorial services were held one week later at which President Timothy Dwight Woolsey gave the principal discourse. He paid high tribute to his associate and friend. Among other things he said, "His colleagues and

friends have regarded him as a born teacher, as possessing a most happy union of several powers, the capacity to convey instruction with clearness, system and elegance, the capacity to impress the pupil with the importance of the subject."

The Planets in June, 1946

By LELAND E. CUNNINGHAM

NOTE: The time employed is Central Standard Time unless otherwise indicated. The phenomena have been chosen and described for the North American continent, and especially for the United States. The basic data have been taken principally from the *American Ephemeris and Nautical Almanac.*

Sun. The sun will be nearly stationary in declination throughout June. It will reach its northernmost point at the beginning of summer, which occurs June 21, at 6:45 P.M., C.S.T. The recent large sun-spot suggests that a daily look at the sun with a small telescope may be well rewarded over the coming months. Let me urge those not familiar with using a telescope on the sun *never* to look at the sun directly even through a dark glass, but *always* to project the sun's image onto a clean sheet of white paper.

A small partial eclipse of the sun will occur on June 28; it will be visible only in the Arctic regions. At greatest eclipse less than one-fifth of the sun's diameter will be obscured.

Moon. The phases of the moon will occur as follows:

	C.S.T.
First Quarter	June 6 10 A.M.
Full Moon	14 1 P.M.
Last Quarter	22 7 A.M.
New Moon	28 10 P.M.

A total eclipse of the moon will occur on June 14, but no part of it is visible on the North American continent; it will be visible principally in and around Asia.

An occultation of Venus on June first will be visible throughout the Mountain and Pacific states; it will begin some two or three hours before sunset, and so considerable optical aid may be required to see it satisfactorily.

Evening and Morning Stars. There will be no morning star in June. The evening stars will be Mercury, Venus, Saturn, Mars, and Jupiter; at the beginning of the month their angular distances east of the sun will be in the order named. Saturn will be overtaken by Venus on June 12, and by Mercury on June 23. Mercury will be visible low in the west just after sunset during the last few days of the month, by which time Saturn will be too low to be seen; Venus will be a very conspicuous object in the western twilight, Mars will be an inconspicuous object somewhat higher in the west, while Jupiter will be a bright object near the meridian at dusk.

Mercury. At the beginning of the month Mercury will just be emerging from superior conjunction with the sun; it will move eastward more rapidly than the sun, and will become visible low in the western twilight before the end of the month. On the evening of June 23 it will be about three diameters of the moon

north of Saturn; both will be inconspicuous objects, and a good test of observing conditions.

Venus. Throughout the month Venus will continue to move eastward a little faster than the sun; it will be a conspicuous object each evening. On the evening of June first it will be very close to the moon as seen from the eastern part of the United States, while farther west there will be an occultation, as described above.

Mars. Mars will move eastward across Leo, but more slowly than the sun, and so will set earlier each night. Near June 18 it will be about two diameters of the moon north of Regulus, and will be slightly the fainter of the two.

Jupiter. Jupiter will be stationary in Virgo; its entire motion during the month will be contained in an area of the sky no larger than the disk of the moon. On the evening of June 8 the moon, Jupiter, and Spica will again be lined up as they were in May. On the evening of June first all four Galilean satellites will be close together west of the planet.

Saturn. Saturn will continue its slow eastward motion in Gemini some ten degrees south of Castor and Pollux, but will be too far west for telescopic observation. It will be near Mercury on June 23, as mentioned above.

On February 14 of this year a small white spot was seen in the equatorial belt of Saturn by observers at Meudon, near Paris, in France; no other observations of this spot are yet at hand. Such spots are useful in determining the period of rotation of the planet, but unfortunately they occur very rarely.

Uranus. Uranus will remain in Taurus, where it will be too close to the sun for observation. On June 8 it will be in superior conjunction with the sun, that is, it will be nearly in line with the sun and earth, and beyond the sun, of course.

Neptune. Neptune will be stationary in Virgo; its entire motion during the month will be contained in an area of the sky having a diameter only one-seventh that of the moon's disk.

Berkeley, California, April 12, 1946.

Occultation Predictions for June, 1946

(Taken from the *American Ephemeris*)

Date 1946	Star	Mag.	IMMERSION Greenwich C.T.	*a*	*b*	Angle E from N	EMERSION Greenwich C.T.	*a*	*b*	Angle E from N
Occultations Visible in Longitude +72° 30′, Latitude +42° 30′			h m	m	m	°	h m	m	m	°
June 10	598 B.Virg	6.5	4 45.1	−1.4	−1.3	83	5 46.2	−0.7	−2.5	331
11	6 B.Libr	6.2	2 27.3	−2.7	+0.1	81	3 33.7	−1.0	−2.4	343
12	β Scor	2.9	23 3.6	+0.3	−1.0	158	23 54.1	−1.5	+2.1	254
19	37 Capr	5.8	8 32.2	−2.4	−0.2	99	9 42.5	−1.0	+0.9	211
22	33 Pisc	4.7	9 1.1	..	..	344	9 23.2	−4.4	−2.1	311
Occultations Visible in Longitude +91° 0′, Latitude +40° 0′										
June 10	598 B.Virg	6.5	4 15.4	−2.0	−1.3	107	5 35.6	−1.2	−2.2	317
11	6 B.Libr	6.2	1 47.4	−1.5	−0.2	120	3 13.3	−1.7	−1.0	310
19	37 Capr	5.8	7 51.2	−1.9	+0.9	88	9 13.5	−1.8	+1.1	231
26	33 B.Taur	6.3	8 55.6	+0.5	+1.9	27	9 34.6	−0.2	+0.9	287

OCCULTATIONS VISIBLE IN LONGITUDE +120° 0′, LATITUDE +36° 0′

				h	m	m	m	°	h	m	m	m	°
June	1	VENUS	−3.4	23	43.0	−2.2	−0.1	77	1	2.2	−1.1	−2.0	295
	3	9 Canc	6.2	5	32.0	+1.2	−3.2	168	5	54.1	−0.6	+0.6	221
	7	ρ Virg	4.2	7	45.1	−0.4	−1.4	97	8	41.1	+0.1	−1.9	317
	10	598 B.Virg	6.5	3	37.2	−0.5	−2.4	168	4	45.8	−3.0	0.0	269
	19	37 Capr	5.8	7	10.2	−0.5	+0.9	104	8	16.1	−1.4	+2.0	232
	22	24 B.Ceti	6.0	10	34.3	−0.6	+2.7	17	11	28.6	−2.0	+0.7	282

OCCULTATIONS VISIBLE IN LONGITUDE +98° 0′, LATITUDE +30° 0′*

June	7	*C* Virg	5.1	23	19.1	−2.0	+0.4	100	0	35.9	−1.2	−2.3	333
	10	598 B.Virg	6.5	4	17.4	−1.8	−2.0	136	5	45.0	−1.8	−1.7	293
	11	6 B.Libr	6.2	1	49.0	−0.5	−2.0	160	3	3.2	−3.0	+0.2	274
	19	37 Capr	5.8	7	30.2	−1.8	+0.4	106	8	43.7	−2.0	+2.2	218
	19	ε Capr	4.7	9	58.9	..	..	357	10	35.9	..	..	310
	22	33 Pisc	4.7	8	7.7	..	..	350	8	25.2	−1.8	−3.0	319
	22	24 B.Ceti	6.0	10	44.9	−1.7	+1.7	55	12	8.1	−1.8	+1.5	232

*Computed by Edgar W. Woolard and Paul Herget; communicated by Commodore J. F. Hellweg, Superintendent U. S. Naval Observatory.

The quantities in the columns *a* and *b* are given for the purpose of making these predictions useful for any place within 200 miles of the point indicated. The procedure is as follows: Subtract the longitude of the point given from the longitude of the place in question; multiply the result in degrees, taking the signs into account, by the quantity under *a* for the star to be observed; similarly, with the latitude, using *b;* apply the sum of the products, with its proper sign, to the Greenwich C.T., and obtain the predicted Greenwich Civil Time for the phenomenon at the place of observation. To obtain Eastern Standard Time it is necessary to subtract five hours; Central Standard Time, six hours, etc.

Asteroid Notes

By HUGH S. RICE

JUNO at the end of May is approximately 4½° east of Delta Viriginis, with a visual magnitude about 9.8 and becoming fainter. It does not attain good brightness at this apparition, being dimmer at its best in April than its mean opposition-magnitude of 8.7.

IRIS is retrograding, mostly in Ophiuchus, following the ecliptic and a little south of it. In the early evening of June 9 for our time zones, there is a conjunction of this minor planet with Antares, IRIS being 3½° north of the star. The magnitude is about 9.6 and becoming fainter. At the end of the period concerned, it is about ½° north of Messier 80. The latter object, also known as N.G.C. 6093, is a globular star cluster in Scorpius, and a compressed mass of fine stellar points. It reminded the old observers of a comet; in fact, Messier said it resembled a comet nucleus. M 80 is the one that Wm. Herschel called *the richest and most condensed mass of stars which the firmament can offer to the contemplation of astronomers,* according to Smyth, *A Cycle of Celestial Objects,* v. 2, the *Bedford Catalogue,* 1844. This famous book of Smyth's was a monumental work and contains some magnificent descriptions of celestial objects.

HERCULINA was discovered on April 24, 1904, by Wolf at Königstuhl. The asteroid was then of magnitude 9.2 and was followed to August 2. It is probably the last minor planet to be discovered, with a mean opposition-magnitude

brighter than 10.0. It is now retrograding in the southern part of Serpens Cauda, in an interesting region of the heavens. While there are no bright stars very close, in the surrounding areas, many Messier objects can be located. The magnitude is probably 9.5 to 10 at its brightest in June.

PALLAS is beginning another apparition and is now retrograding in eastern Hercules, south of Vega. The visual magnitude during this period is about 8.9, and it comes to opposition on June 27. This is one of the best minor planets for observation this summer.

VICTORIA was discovered on September 13, 1850, by Hind at London, and was followed for 6 months thereafter. The magnitude at discovery was 8.5. At first the asteroid was known—at least in this country—as *Clio*. [There is now another planet called *84 Klio*.] The mean opposition-magnitude of VICTORIA is 9.7. At this time, it is in the southern half of Scutum, east of HERCULINA, with few neighboring bright stars, but within the Milky Way. The magnitude is about 9, approaching maximum at opposition, June 29.

ASTEROID EPHEMERIDES

For 0^h U.T. Equinox of Date

3 JUNO

1946		α h m	δ ° ′
May	25	13 12.3	+ 3 50
	30	13 11.1	+ 3 53
June	4	13 10.4	+ 3 52
	9	13 10.1	+ 3 48
	14	13 10.3	+ 3 40
	19	13 11.0	+ 3 29

7 IRIS

1946		α h m	δ ° ′
May	25	16 42.6	—23 51
	30	16 37.5	—23 34
June	4	16 32.2	—23 15
	9	16 27.0	—22 55
	14	16 22.0	—22 36
	19	16 17.3	—22 16
	24	16 13.1	—21 56

532 HERCULINA

1946		α h m	δ ° ′
May	25	18 6.8	—11 27
	30	18 3.2	—11 46
June	4	17 59.0	—12 7
	9	17 54.5	—12 30
	14	17 49.8	—12 57
	19	17 44.9	—13 25
	24	17 40.1	—13 55

2 PALLAS

1946		α h m	δ ° ′
May	25	18 46.6	+22 17
	30	18 43.9	+22 49
June	4	18 40.8	+23 15
	9	18 37.2	+23 36
	14	18 33.4	+23 49
	19	18 29.4	+23 55
	24	18 25.2	+23 54

12 VICTORIA

1946		α h m	δ ° ′
May	25	18 50.6	—15 41
	30	18 50.0	—14 57
June	4	18 48.5	—14 12
	9	18 46.2	—13 29
	14	18 43.1	—12 47
	19	18 39.4	—12 8
	24	18 35.3	—11 32

Hayden Planetarium, American Museum of Natural History,
New York, N. Y., April 23, 1946.

METEORS AND METEORITES

Meteor Notes from the American Meteor Society

By CHARLES P. OLIVIER, President

The present Notes contain the annual report for 1945 and the list of new members who have joined since May, 1945, when the last such list was published. During the past year our Society has prospered, considering the disturbed state of the world and the fact that many of our best and most active observers are still in service. F.O.R. No. 66, containing the Notes for 1945, has been distributed to all who have paid their 1946 dues. Others will receive it when their dues have arrived here. A special unnumbered reprint, covering the November and December Notes, which contained data and discussion of the 1945 Perseids, was mailed to all who participated last summer, as well as to all new A.M.S. members. Sending this to casual observers appears to greatly increase their interest and encourage them to observe in coming Augusts. It has also netted us several new members.

Outstanding work in 1945 by various observers has been mentioned from time to time. Here again special commendation should be given to Professor Mohd. A. R. Khan of India for his very numerous and valuable reports, and to C. F. Fernald of Wilton, Maine, for sending in observations of 56 of the total of 67 telescopic meteors for the year. Professor J. Hugh Pruett of the University of Oregon, our regional director for the extreme N.W. of our country, was, as usual, instrumental in keeping up much interest in meteors throughout his territory and sending in many valuable data on fireballs.

This opportunity is taken, well in advance, to urge upon all regional directors and active members in general the advisability of preparing for the summer and fall showers. The August meteors, particularly, attract much popular attention and it is not difficult to secure observers. Cannot members plan a good campaign for the Perseids without the writer having to remind them and urge them into activity? We need these observations every year if we would have data for a proper study of this most regular of all prominent meteor streams. Requests for maps and blanks, which will be needed, should reach me some weeks in advance not at the last moment.

The writer has been at work on an extension of his paper on long-enduring meteor trains which appeared in F.O.R. No. 60. He hopes to have this ready for publication within a few months. We also expect to have an enlarged staff for the Flower-Cook Observatories next session which should permit some increase in reduction and publication of results.

In the table we find in order: the name of observer, his address (or station where work was done), the number of nights on which a reasonable amount of time was spent observing, the total number of meteors recorded in 1945, and finally remarks. In this last column P means that the meteors were plotted, D described, and C counted. An asterisk (*) means that two or more observers took part but, to save space, the meteors are assigned to the person who reported for group. Reports of persons, 35 in number, who sent in less than 20 meteors for

the whole year, are included under title Casuals. Many of their names and what they did appeared in the November Notes.

Observer and Station	Nights	Meteors	Remarks	
Anderson, R., Chicago, Ill.	2	116	PC	
Bates, J., Ithaca, N. Y.	2	104	CD	
Beetle, Mrs. D. E., Davis, Calif.	2	90	P	
Bidlake, Miss M., Pullman, Wash.	4	543	C	
Binkley, A. M., Florence, Ala.	1	31	C	*
Blaser, J., Fresno, Calif.	4	180	C	
Bones, B. R., Grants Pass, Ore.	1	101	C	
Bostick, Dr. J. B., Fresno, Calif.	3	87	C	
Brooks, C. H., Slinger, Wis.	2	65	C	
Bryson, J., Eugene, Ore.	1	20	C	
Burlinson, M. A., Tucson, Ariz.	2	65	CP	*
Burn, E., Wallingford, Pa.	1	53	P	
Cooke, M., Oak Bluff, Mass.	2	98	P	
Crotona Observers, Bronx, N. Y.	13	171	P	*
Cuthbertson, A. M., Palo Alto, Calif.	1	46	C	
deWolfe, Mrs. C., River Edge, N. J.	1	55	C	*
Dole, R. M., Cape Elizabeth, Me.	16	837	PD	
Dukon, W. J., Sioux Falls, S. D.	1	274	C	
Edmonds, A., Vancouver, B. C.	1	25	D	
Ehman, C., Hartford, Conn.	13	186	P	
Ehman, Mrs. C., Hartford, Conn.	2	54	C	
Epstein, E., New York, N. Y.	1	20	P	
Fitzsimmons, C. S., Sibley, Iowa	4	224	P	
Flegal, P. S., Hurlock, Md.	2	49	D	
Gaston, M. C., Grants Pass, Ore.	1	85	C	
Gorson, R. O., U.S.N.	1	48	PD	
Graham, J. L., U.S.N.	3	54	C	
Graves, Mrs. P. E., Saco, Me.	3	137	C	
Griffith, Miss J. T., Sarasota, Fla.	1	28	P	
Haas, W. H., Flower Observatory, Pa.	1	100	PD	*
Halbach, E. A., Milwaukee, Wis.	1	72	CD	*
Hay, A. A., Chicago, Ill.	1	24	P	
Henchman, J. M., LaCanada, Calif.	1	470	C	
Herbert, J. T., Bucks Co., Pa.	2	156	C	
Hochschild, Baltimore, Md.	2	114	C	
Holderreed, F. L., Anaconda, Mont.	1	190	C	
Hukill, R. M., Wilmington, Del.	5	91	P	
Hurdle, Mrs. H. F., Yuba City, Calif.	5	130	C	
Jamison, Miss E., Prescott, Ariz.	1	31	C	
Jensen, Miss A. K., Silverton, Ore.	6	218	C	
Karsner, Mrs. K. H., Rose Valley, Pa.	4	212	C	
Khan, Professor Mohd. A. R., Begumpet, India	55	731	PD	
Kirby, Miss E., Big Basin, Calif.	2	537	DP	*
Kline, H., Cape Cod, Mass.	2	204	C	
Komaki, K., Kanaya, Japan	5	171	PC	
Krechten, S. E., McSherrystown, Pa.	1	31	C	
Larmay, F., Flint, Mich.	8	48	P	
Ledbetter, H. E., Norman, Okla.	7	96	P	
Liss, A., Philadelphia, Pa.	3	166	D	
Long, Mrs. B., Dell Rapids, S. D.	2	594	C	*
Lupton, Dr. B. M., Hackensack, N. J.	2	29	C	*
McClave, Miss E. L., No. Colebrook, Conn.	1	55	C	*
McNaught, Miss M., Ridgewood, N. J.	1	37	C	
McNeill, W. S., Charlottesville, Va.	3	638	C	
McWilliam, J., Limeton, Va.	3	27	C	
Marshall, R. K., Cook Observatory, Pa.	2	117	C	
Mocharnuck, N., Woodstock, N. J.	2	292	C	*
Nixon, A. H., Marianna, Ark.	2	52	D	

Observer and Station	Nights	Meteors	Remarks	
Oberst, W., Pasco, Wash.	1	56	C	
Olivier, C. P., Flower Observatory, Pa.	5	145	PD	
Oravec, E., Yonkers, N. Y.	9	239	D	
Parmenter, B. C., Seattle, Wash.	1	32	P	
Pillans, Miss H., So. Hadley, Mass.	3	253	CP	*
Preucil, F., Joliet, Ill.	6	171	C	*
Rasmussen, H., Boca Raton, Fla.	1	51	C	
Richardson, T., Norman, Okla.	14	415	P	
Romeri, R., E. White Plains, N. Y.	1	93	C	
Rosengarten, G., Brookline, Pa.	2	110	C	
Roth, D. D., Fairfield	1	95	C	
Russell, O. E., Rockford, Ohio	8	84	D	
Rust, M. D., Casa Grande, Ariz.	1	40	C	
Sanders, R., Dallas, Texas	3	93	P	
Sandmeyer, Miss E., Buhl, Idaho	9	121	CP	
Schermerhorn, Miss H., N. Chatham, Mass.	2	126	D	
Schilling, J., State College, Pa.	16	109	P	
Shumanich, A., Wilkes-Barre, Pa.	1	29	C	
Shutts, R. V., No. Hills, Pa.	4	58	P	
Skinner, G. B., Brockton, Mass.	4	51	D	
Smith, C. H., Waterloo, N. Y.	2	127	C	*
Smith, K. D., Vancouver, B. C.	1	29	C	
Smith, Miss L. M., Milton, Pa.	1	246	C	*
Spiess, E., Manchester, Conn.	3	533	C	*
Stolnabb, C. P., N. Wildwood, N. J.	1	26	C	
Stowe, B., Bronxville, N. Y.	8	223	P	
Swihart, T., Elkhart, Ind.	3	51	P	
Talaporos, A., Camp Manhattan, N. Y.	2	95	D	
Thompson, Miss A. J., Eugene, Ore.	1	37	C	*
Thorsheim, B., Clinton, Wash.	4	55	C	
Van Derpool, C., Towanda, Pa.	2	44	D	
Van den Nort, Miss V., So. Hadley, Mass.	2	57	P	
Van Schoiak, Mrs. F., Prineville, Ore.	1	50	C	
Veal, H. K., Ratliff, Okla.	8	309	P	
Wagner, D. H., Williamsport, Pa.	2	80	D	
Waldmann, E., Yonkers, N. Y.	21	284	D	
Wakefield, G., Wenonah, N. J.	1	28	C	
Wheeler, K. W., Cincinnati, Ohio	1	40	C	
Wilf, H., New York, N. Y.	1	30	P	
Wildmann, E. E., Pocono Manor, Pa.	1	312	C	*
Wimmer, Mrs. C. C., Scottsbluff, Neb.	2	167	C	*
Wood, Lieut. R. J., U.S.N.	2	1107	CP	
Wrinn, J. J., Nangatuck, Conn.	10	210	CP	
Ziegler, Miss B. A., Gettysburg, Pa.	1	21	C	
Missouri-S. Illinois Group (1940-1943), near St. Louis Mo.		423	C	*
Komaki, K., (1941), Kanaya, Japan	3	28	P	
McKeon, Mrs. J. J., (1944), Titusville, N. J.	5	113	P	
McKeon, J. J., Titusville, N. J.		303	CPD	
Casuals (35)		203	CPD	
Fireballs		114	PD	
Telescopic		67	DP	
Grand Total		17,087		

We should have more reports on fireballs from ships in 1946 than in recent years, and we also hope (probably in vain!) that we can induce more variable star observers to record telescopic meteors. Finally we extend a hearty invitation to all persons, really interested in meteoric astronomy, to write us with a view to joining the A.M.S.

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Contributions of the Society for Research on Meteorites

Edited by FREDERICK C. LEONARD
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A Preliminary Note on the Exclusively Meteoritic Minerals

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ABSTRACT

It is shown in this preliminary note that the earlier lists of the exclusively

meteoritic minerals are in error. On the basis of a review and an analysis of the available literature, it is proposed that a *tentative,* revised list of these minerals should include the following: daubréelite, kosmochlor, merrillite, oldhamite, osbornite, phosphorus, schreibersite, taenite, and weinbergerite.

Soon after beginning a term paper on the exclusively meteoritic minerals for a course in meteoritics, taught by Dr. Frederick C. Leonard of the Department of Astronomy of the University of California, Los Angeles, in the spring of 1945, it became evident that the previous lists of exclusively meteoritic minerals were considerably in error. The errors were due largely to non-recognition of the accepted definition of a mineral. The definition of a mineral is of prime importance in deciding whether a mineral does or does not occur terrestrially; *e.g.,* moissanite, oldhamite, osbornite, and phosphorus are all represented terrestrially only by artificial products or in slags from blast furnaces; yet moissanite and oldhamite are included in earlier lists of the exclusively meteoritic minerals, altho osbornite and phosphorus are excluded, apparently for this very reason! The minerals of the present list all satisfy the definition of a mineral as given in the 4th Edition of *Dana's Textbook of Mineralogy*:[8] "A Mineral is a body produced by the processes of inorganic nature, having usually a definite chemical composition and, if formed under favorable conditions, a certain characteristic atomic structure which is expressed in its crystalline form and other physical properties." This definition is construed specifically to exclude the products of laboratories and blast furnaces.

The minerals and non-minerals first reported from meteorites consist of the following:[6, 16] cohenite, daubréelite, kamacite, kosmochlor, lawrencite, maskelynite, merrillite, moissanite, oldhamite, osbornite, phosphorus, plessite, schreibersite, taenite, and weinbergerite. Of these, some have been found to occur naturally on the Earth; others are yet to be found; and still others are not minerals, are discredited as mineral species. Three lists of exclusively meteoritic minerals were found in the literature. Farrington[6] listed daubréelite, maskelynite, moissanite, oldhamite, schreibersite, and weinbergerite, stating that the other minerals first described from meteorites are *similar* to terrestrial minerals. Heide[10] listed daubréelite, lawrencite, maskelynite, moissanite, oldhamite, rhabdite (a certain habit of schreibersite), and schreibersite. Nininger[21] simply added merrillite to Farrington's list, it having been discovered shortly after the publication of that list. Of the 15 minerals and non-minerals previously enumerated, it appears that only the following ones are exclusively meteoritic: daubréelite, kosmochlor, merrillite, oldhamite, osbornite, phosphorus, schreibersite, taenite, and weinbergerite. In view of the definite lack of information concerning many of these minerals, the present list is offered only as a tentative one. Several of the minerals are included or excluded, admittedly on a questionable basis only.

Cohenite ($(Fe, Ni, Co)_3C$) has been found in the terrestrial irons of Greenland.[24]

Kamacite (Fe, Ni) and taenite (Ni, Fe) are "border-line" minerals, inasmuch as they are alloys of variable composition,[23] and are represented terrestrially by similar nickel-iron alloys.[23] It seems that in order to establish the identity of such minerals as these with terrestrial minerals, it is necessary for the terrestrial minerals to have the same structures as the meteoritic minerals. Since this appears to be the case for kamacite,[23] it is excluded from the present list.

The nickel-iron alloys of the Earth that are of a composition similar to that of taenite are apparently not reported to exhibit any such structural similarity. Moreover, Henderson[11] states that he does not think that there is a single authentic occurrence of terrestrial taenite; hence taenite is included in the present list.

Kosmochlor ($Al_6 Fe_4 Cr_{18} Si_{18} O_{78}$) (Kosmochromit)[9] was first reported by Laspeyres[16] and was described as coming only from a Xiquipilco = Toluca, Mexico State, Mexico, siderite (Om). It was subsequently mentioned by Groth,[9] Cohen,[3] and Hintze.[13] As no material of similar composition has been recorded as occurring terrestrially, it is included in the present list, altho this is a case in which corroborative work and more exact information are wanting.

From the literature, the impression is gained that little is known about lawrencite ($(Fe, Ni) Cl_2$). No properties are given for the mineral in its solid form. It has been studied apparently only as a solution composed of nickel and iron chlorides, presumably of cosmic origin, and evidently not as a product due to contact with the Earth. In view of this lack of critical information concerning the solid mineral lawrencite, it should be excluded from the list of exclusively meteoritic minerals until such time as its characters can be accurately determined and compared with those of the known terrestrial iron chlorides; moreover, lawrencite is doubtfully reported from the native irons of Greenland.[11]

The work of Merrill[20] and Lacroix[15] has definitely established Tschermak's view that maskelynite represents, without a doubt, a re-fused plagioclase feldspar. Merrill found the maskelynite in a Holbrook, Arizona, aerolite (Cck) to have the same index of refraction as that of oligoclase glass. Lacroix added the final proof when he demonstrated that the variability of composition of maskelynite conforms to that of the plagioclase series.

Little is actually known about merrillite ($Ca_9 Na_2 P_2 O_8$), altho it has been extensively studied.[17, 18, 19, 25, 26, 28] Critical X-ray data and sufficient analyses are wanting to compare it with the terrestrial members of the complex apatite isomorphous series of which it is a member.[17] In view of its close similarity to dehrnite,[17] it seems likely that a terrestrial occurrence of merrillite could be readily found. As there is no substantial evidence of such an occurrence, however, it is retained in the present list.

Moissanite (SiC) has been reported as occurring in sediments of all ages.[22] The source is presumably meteoritic. It is almost certain, however, that this reported occurrence is due to contamination from a carborundum paste used in cleaning water taps.[4]

Oldhamite (CaS), because of its chemical composition, probably does not occur terrestrially, but a reference is made by Hintze[12] to the possible occurrence of CaS (or MgS or SrS) in a marble from Cintra, Province Estremadura, Portugal. The evidence presented is far from being conclusive, Hintze himself having considered it of little value. The presence of the alkaline sulfide was apparently attributed to the evolution of H_2S upon striking or scratching. As the original article[14] was unavailable, and as the evidence presented is not convincing, oldhamite is retained in the present list as an exclusively meteoritic mineral.

Osbornite (TiN) has apparently been discredited as an exclusively meteoritic mineral in view of the not uncommon finding of material with the same properties and composition in slags from blast furnaces.[1, 27] This circumstance cannot be construed as constituting a proof of a natural terrestrial occurrence; hence, the mineral is included in the present list.

Phosphorus (P_4) has been reported as occurring naturally in the Saline Tp., Sheridan Co., Kansas, aerolite (Cck) by Farrington.[5] As no subsequent attempt has been made to prove or to disprove this occurrence, and, as the natural presence of phosphorus in the free state is considered most unlikely, the reported occurrence is thought to be very doubtful. As it is not impossible that Farrington *did* find free phosphorus in the previously mentioned meteorite, and as "doubts" are not evidence, the element is included in the present list.

Plessite is not a mineral at all, the word *plessite* being properly used only as a structural term. The material is an intergrowth of kamacite and taenite on a microscopic scale.[7]

Weinbergerite ($NaAlSiO_4 \cdot 3FeSiO_3$) is in a position similar to that of kosmochlor. Information as to its properties is incomplete, and it does not seem likely that a mineral having such a composition should be exclusively meteoritic. From Berwerth's[2] article, it is evident that he assumed that the dust-like inclusions in weinbergerite had the same chemical composition as, but differed in structural composition from, that mineral. Such an assumption is unfounded and suggests that the formula given for weinbergerite is incorrect. If the formula is incorrect, weinbergerite may well be identical with a known terrestrial mineral; in the absence of definite proof to the contrary, however, it is included in the present list.

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An Announcement to Collectors of Meteorites concerning the Pantar, Lanao, Philippine Islands, Fall

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ABSTRACT

Herein is related how the aerolites from the Pantar, Lanao, Philippine Islands, fall of 1938 June 16 escaped the Japanese invasion of the Philippines. On behalf of Mr. H. J. Detrick, thru whose painstaking efforts the collection of these aerolites was made possible and the specimens themselves were preserved, an appeal is made to collectors of meteorites.

In 1941, the American Meteorite Laboratory received a collection of 13 aerolites from Mr. H. J. Detrick, a hotel operator in Dansalan, Lanao Province, Mindanao, Philippine Islands. These specimens constituted the bulk of the stones that were recovered from the Pantar, Lanao, fall of 1938 June 16 (coördinate number = *1243*,081).[1] Mr. Detrick, who had been a friend of mine since our boyhood in Oklahoma, instructed me to keep what specimens I wanted for my own collection and to dispose of the remainder for him. The collection was accompanied by an uncommonly good set of data concerning the fall, including several maps of the area, an extensive survey based upon "on-the-spot" interviews with observers, results of a neighborhood canvass for ascertaining significant facts of light and sound, and an excellent series of photographs of the cloud left in the wake of the brilliant daylight meteor caused by the falling aerolites. These data are being preserved for later publication in a full report of this important fall.

Mr. Detrick was well prepared to make good use of the opportunity that this event presented. Trained at McPherson College, McPherson, Kansas, he began his career in the Philippines in 1908 as a high-school teacher in Bayombong. A year later, he was promoted to the position of Supervising Teacher and Assistant to the Governor of Nueva Vizcaya Province. From that position he was rapidly promoted in educational and governmental work, becoming Governor of the Province of Palawan in 1915. Later, after retiring from political life, he became the manager of a large plantation, and also engaged in mining and lumbering. In 1939, he opened a hotel in Dansalan, Lanao, Mindanao Island, which he operated until the Japanese occupation, when he was stripped of all of

his possessions and, together with his wife, was made a prisoner of the invading Japanese. Our correspondence concerning the meteorites was suddenly terminated by the war. I made no effort to dispose of them, for I suspected that my friends had lost their life savings to the enemy and that these few specimens might serve as their post-war start in life—a start that would be meager enough indeed, for people of their age!

After the Japanese surrender, word from the Detricks was eagerly awaited, but it was June or July, 1945, before any word was received. When it finally came, we learned that our friends had been thru more than 3 years of suffering in Japanese prison camps, that they were both broken in health, were emaciated from lack of food, and were suffering from beriberi and other ailments. They, in company with 2100 others, had been liberated on the morning of February 23, 1945, from Los Banos Prison, in that daring rescue carried out jointly by paratroopers and by land and water forces only 15 minutes before the time set by General Yamashita for the slaughter of the entire camp!

The collection of meteorties began to assume historic as well as scientific value. Had these specimens and the data concerning them been allowed to remain in the Philippines, some very important facts would have been lost to science, and it is doubtful whether even the specimens themselves would have been preserved. The members of the staff of the American Meteorite Laboratory are proud and happy to have been privileged to coöperate in this important contribution to the science of meteoritics.

Mr. Detrick is not a collector. His wish from the first has been to see these specimens and the data that he so carefully gathered disposed and made use of in whatever manner may best serve the interests of the young science of meteoritics. In a letter to me dated April 13, 1939, he wrote: "You will not believe this, but, all the while that I have been collecting these data and specimens, it has been my purpose to send everything to you." He has insisted, even since his liberation, that I accept whatever I want from the stones, gratis. In view of his present situation I cannot do this, but will pay for the stones that I keep at the same rate as may be paid for the other specimens. As a scientist, I want these specimens to go where they will best serve to advance the study of meteorites. As a friend of the owner, I want them to bring the best price consistent with their important place among the meteorites of the world.

Several factors render these Pantar aerolites more desirable for collections than are the representatives of similar falls of corresponding magnitude: (1) The cloud that was left in the wake of the falling meteorites was seen by thousands of people and was successfully photographed. Copies of these photographs will be available with the specimens. (2) This fall was witnessed by many people. (3) This is one more case where we have abundant testimony as to the showering of small particles of meteoritic matter in connection with the fall of meteorites. Many natives testified to the "patter of small grains," of the size of corn or rice grains, on the galvanized-iron roofs of their houses. Mr. Detrick gathered and preserved several samples of the soil from the grounds around these houses. These samples of soil have not yet been examined, but it seems probable that they may yield some of these minute aerolitic particles. (4) The geographical location of the fall gives it distinction. Only 2 other meteoritic falls have thus far been recorded for the Philippine Islands.[2] (5) An unusually accurate plat of the dis-

tribution of the 16 individuals collected from this fall has been made and will eventually be published.

The Pantar aerolites have not as yet been analyzed, but a casual examination of them indicates that they belong to one of the numerous groups of chondrites (C). The stones are for the most part almost completely incased in a typical fusion crust; they are only slightly stained with rust in a few spots. All in all, a representative of this fall would constitute an excellent addition to any collection of meteorites.

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[2] [The other 2 known Philippine falls are *1227*,117, Calivo, Panay Is., A: Acb?, and *1211*,146, Pampanga, Luzon Is., Cgb. (In each case, the coördinate number precedes the name of the fall, while the symbol for the class follows it.) —ED.]

Meteors, Burning Planes, and Rockets

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ABSTRACT

This article presents one more reason for the teaching of meteoritics in high schools as well as in colleges. Proper insight into the nature of meteorites and meteors would reduce confusion between meteors and burning planes. This understanding would save both lives and property and at the same time would increase the efficiency with which meteoriticists could attack the problem of meteor surveys.

Confusion in the minds of observers has for many years existed because of the resemblance between burning airplanes and large, distant meteors. The latter are commonly mistaken for burning planes and are reported as such by persons eager to assist in the rescue of the luckless pilot and crew. The motive is laudable enough and should not be discouraged; on the other hand, such a mistake often results in needless waste of property and endangers the lives of other pilots who participate in the search. Until recently this problem was readily handled by experienced meteoriticists to whose attention such cases were brought. By "contacting" observers in several widely separated locations it was comparatively easy to determine the approximate distance. With a knowledge of the distance it was possible, even from very amateurish reports, to judge whether the speed of the object fitted better into the pattern of a plane or into that of a meteorite. Moreover, when all kinds of aircraft were limited to heights of a few thousand feet, while meteors vanish normally above an elevation of 5 miles, it was often possible to decide promptly whether a plane or a meteorite fell, on the basis of the approximate height. Now, however, when aircraft may invade the stratosphere; when airplane velocities have been increased to more than 500 miles per hour; and when rockets threaten to streak the sky with fiery trains at speeds of thousands of feet per second, problems arise which are likely not only to trouble the meteoriticist but also definitely to endanger both life and property thru failures or delays in distinguishing between cosmic and terrestrial objects.

I have previously urged the importance of offering a course in meteoritics

for the purpose, among other things, of promoting a general understanding of the most outstanding identification marks of meteorites. I have tried to emphasize that this most fundamentally distinct group of all rocks should, insofar as the common varieties are concerned, be made generally recognizable by the public, so as to render possible the gathering of more material for investigation. Now comes an additional and a very urgent reason why a course in meteoritics should be included in the curricula, not only of our colleges but also of our high schools.

We, who have had experience in making meteor surveys, realize how absolutely unprepared is the general public to assist in gathering and reporting facts regarding large meteors. The foreseeable future of aeronautics is going to multiply the difficulty many-fold. As just pointed out, there will almost certainly result much suffering and much loss of life and great property damage unless the public is able to cope with this new situation in the best possible manner, by contributing prompt, intelligent, and reliable reports from whatever quarter the fiery trains may be visible. The science of meteoritics also will suffer, for the reason that the increased number of mistakes which will be certain to accompany aeronautical expansion will discourage the uninformed and will result in many important meteors' not being reported promptly by those who have made the observations which we need so badly for use in our surveys. Once a valid foundation has been laid in our schools, the press and the radio will stress the importance of the work and will make the plan effective; at the present time, however, those who have an adequate grasp of the situation are so few in number that even well-meaning writers for the press, and radio announcers, frequently add to the confusion instead of helping the situation.

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VARIABLE STARS

Variable Star Notes from the American Association of Variable Star Observers

By LEON CAMPBELL, Recorder

Reaching for the One Million Mark

The year 1946 will long stand as a landmark in the annals of the AAVSO as the year in which the long sought-for goal of attaining the total of one million observations of variable stars was reached.

Little did our first secretary, the beloved William Tyler Olcott, think way back in 1911 and 1912, that the members of the Association would accomplish this remarkable feat, for a real feat it must be called. To be sure, it has taken thirty-five years to attain this goal, but it all goes to show what can be achieved, even among amateurs, by concerted effort on the part of an enthusiastic group of scientifically-minded persons.

The progress toward this goal has not been made too easily. During the early years there were many obstacles to hurdle; chief among them was that of

the observing charts which had to be supplied to our tyros, some of whom had no more than a love for the stars and the desire to play a part in what was explained to them to be the most worthwhile phase of astronomical research in which they could engage with advantage to themselves and to science.

Olcott did his best to prepare the necessary blueprint charts, ably assisted by Dr. Gray. Many of these charts, as crude as they were acknowledged to be by the makers, well served their purpose. After a few years there was found a real artist in the person of David B. Pickering, known to many of us as "Dave." It was to Dave that we were indebted for putting our observing charts on a most efficient working basis. In this work he was ably assisted by Yalden, the "Baron," and later by D. F. Brocchi, of Seattle, Washington. Pickering worked out a system of charts suitable for the observers with little optical aid, as well as for those who had access to telescopes of considerable size. Since the retirement of Pickering, Mr. Brocchi has ably carried on the chart-making program.

We must not forget that perhaps the greatest assistance to our chart program was given some years ago by Professor S. A. Mitchell of the Leander McCormick Observatory who so diligently carried out the program of revising and extending the magnitude sequences to the fainter stars for the fainter variables. His work enhanced the value of our work, and to him we must all be truly grateful.

In the first few years of our existence, we had the heartiest cooperation and greatest encouragement from Professor Edward C. Pickering, then Director of Harvard Observatory. During the first 25 years we had the whole-hearted support of the Editors of POPULAR ASTRONOMY, in fact until we swamped the columns of that periodical with our variable star observations. For the past ten years our observations have been found in the *Harvard Annals*, a place where we are proud to find them.

During the past 25 years the Association has been fortunate indeed to have had the active encouragement and support of Director Harlow Shapley, of the Harvard Observatory. It is to him, more than to anyone else, that we owe the establishment of the Edward C. Pickering Memorial at Harvard, which insures the perpetuation of variable star observing for many years to come.

It is of interest to note the progress during five year intervals toward the attained goal. The first five years averaged 12,000 observations per year; the second, 13,000; the third, 17,500; the fourth, 24,000; the fifth, 42,000; the sixth, 50,000; while for the past five years the average fell back to 41,000 per year. This decrease in activity is of course well explained as a war casualty. To put it another way, the last half-million estimates of the variables were made during the past 10 years, as against 25 years to attain the first half-million mark. Had it not been for the war we undoubtedly would have passed the first million mark a year or so ago.

Let us for a moment go back over the years and see who have been some of the outstanding observers. Of course, Olcott, who may well be called the originator of the AAVSO, more than did his part, especially in the early years. Then, too, Professor Anne S. Young, of Mt. Holyoke College, and an observer of variable stars for some years preceding the formation of the AAVSO, lent her aid in getting the observing program off to a good start. Dr. Gray, already referred to in connection with our chart program, was one of our earliest observers. Associated with us almost from the start, and now in his 90th year, is

our veteran observer, the Reverend T. C. H. Bouton, of St. Petersburg, Florida, with a record of 25,000 observations. No other observer in our ranks can claim such a *long and continuous* record for sending in reports with so few breaks in continuity. Thirty-five years of variable star observing, especially when one does not start until he has passed the two-score years and ten mark, is a record of which to be proud.

Burbeck, Crane, and McAteer, are names to be recalled as of able and ardent observers. Pickering, Godfrey, and Yalden also helped us to get well started on the up-hill climb to our present-day goal by carrying on an extensive program of observing. R. G. Chandra of Bagchar, India, has been an observer since 1920, with more than 30,000 observations to his credit. Here again, the war greatly interfered with his work during the past five years.

We have had a number of amateur observers who have turned professional. Many thousands of observations were reported by W. J. Luyten, then a student at Leiden, Holland, and now at the University of Minnesota. G. B. Lacchini of Faenza, Italy, also helped us in the observing field from 1912 to 1925, when he gave up amateur observing for the work of a professional astronomer, and he is soon to return to our ranks as an amateur again.

Among other observers in foreign lands who have materially helped to pile up the first million are Messrs. Houghton, Ensor, Cousins and de Kock of South Africa, Bappu of India, Ahnert of Germany, Kanda of Japan, deRoy of Belgium, Baldwin of Australia, and Loreta of Italy. South America has been well represented by Dawson, Segers, and Dartayet of Argentina, and Luft of Brazil. Mexico can claim Maupomé, Escalante, and Taboada as outstanding observers, and from Canada have come numerous contributions in more recent years from Duffie, Garneau, Vohman, Nadeau, and Topham. The initials of three observers stand out very prominently in the published reports. P, for Peltier, J for Jones, and Fe for Fernald. The first mentioned has been observing without interruption since 1918, with at least 70,000 observations to his credit. Jones, since 1923, accumulated nearly 50,000 observations, until failing health forced him to give up observing. Fernald has, in the relatively few years during which he has been keeping track of our variables, accumulated a large number of observations—30,000 since joining our ranks in 1937.

To mention other names, there should be included those of Meek, Rosebrugh, Houston, Halbach, and, not to overlook the ladies, there are Mrs. Winifred Kearns, formerly of Fall River and now of West Bridgewater, Mass., and Mrs. Rosina Dafter, of Australia. If I have not mentioned other persons herein, it is not because they have not done their fair share of observing, but space will not permit the enumeration of every name. It is safe to state that in the past 35 years, the names of over five hundred observers have appeared in the published results. To be sure, many of them made only sporadic observations, tiring after sending in two or three reports, while on the other hand, as shown above, a fair proportion have stuck to their lasts—or rather to their scopes—for many years.

Now to whom goes the credit for having made that millionth observation? Is it one of the beginners, or one of the old school of observers? Not being an accountant, the Recorder can not claim infallibility as to the selection of the one-millionth estimate, because in reckoning up to that million mark, no one could vouch for an accuracy of one in a million. However, since last October,

when we had reached a total of 978,244, the Recorder has kept an accurate tally of the observations as they came in, and he has tried to act fairly and squarely towards all concerned. This one-millionth observation is based on the date of receipt at headquarters, not on the date of actual observation. The distinction of being the one who has contributed the one-millionth observation goes to Dr. William L. Holt, a retired physician of Scarboro, Maine, sometime observer at Tucson, Arizona, Amherst, Mass., and Winter Park, Florida. His report contained 302 observations, 275 more than was necessary to reach the desired goal. Dr. Holt has been observing for us since 1932, and in these past 14 years has made thousands of observations. Being a nomadic sort of gentleman of more or less leisure, he has transported his 8-inch Springfield-type reflector from place to place, thus being enabled to maintain an almost complete observing record.

The millionth observation was made on March 3, and received at headquarters on April 15. The variable star on which this particular observation was made proves to be the long-period variable X Ceti, one of the 500 or more such variables which have been under close scrutiny by the Association for the past 35 years. X Ceti was originally detected as a variable in 1895 by Miss L. D. Wells, from a Harvard plate. It has an early type Me spectrum, a range in variation of about three magnitudes, with a moderately short period for a long-period variable, 177 days, or slightly under six months. It is one of those stars whose maximum is decidedly broader and flatter than its minimum, with rate of increase to maximum about equal to its decrease to minimum.

Now that the first million mark has been reached, we must steadily pursue our way to a still higher goal. With the war over, and more tyros joining up, it looks as though we can get into a stride which will prove to be effective and which will reflect credit to our association. Here, though, allow me to reiterate that *quality*, rather than quantity, should and must be our watchboard. And here's to the second million, years hence!

One who is familiar with the history of the A.A.V.S.O., here so well recounted, is definitely impressed by the fact that the name of one person who played a most important rôle in its development is omitted from the above account. The reason for its omission at once becomes apparent when one notes that it is, indeed, the name of the writer of the account. With his characteristic modesty and humility, we know that Leon Campbell would think of himself last in this connection. But the record, which in many, many places discloses "Leon Campbell, Recorder," gives abundant evidence that A.A.V.S.O. could not have gone forward so steadily and so efficiently had it not been for his diligence and enthusiasm. A.A.V.S.O. is, indeed, his foundling. We take the liberty of adding this item to the story.

—EDITOR.

Comet Notes

By G. VAN BIESBROECK

The only comet which remains under observation at present is COMET 1946 *a* (TIMMERS) discovered on February 2 at the Vatican Observatory. It is now within 10° of Polaris and will remain circumpolar several months longer moving slowly to within a couple of degrees from the pole in July. From an improved orbit L. E. Cunningham has deduced the following ephemeris for the coming month:

1946		α h m	δ ° ′
April	26	6 31.7	+81 3
May	4	6 56.7	82 17
	12	7 43.1	83 26
	20	8 59.2	+84 13.

This should enable observers to locate the object without difficulty. The brightness is expected to drop slowly. There have been some fluctuations in brightness these last weeks, the magnitude hovering between 9 and 10. There have been also some change in the brightness and extent of the tail but on the whole the object does not show any great physical activity.

The search for the expected PERIODIC COMET TEMPEL (2) has not yet led to its recovery. The ephemeris (p. 207) is continued here:

1946		α h m	δ ° ′
May	4	21 18.7	— 8 58
	12	21 45.2	8 2
	20	22 11.9	7 5
	28	22 38.8	6 11
June	5	23 5.6	— 5 21

Williams Bay, Wis., 1946 April 13.

General Notes

Professor J. H. Oort has been appointed Visiting Professor at the Yerkes Observatory for four months, beginning in January, 1947. It is expected that he will give a course of lectures during the Winter Quarter.

Professor M. Minnaert has been appointed Visiting Professor at the Yerkes Observatory for four months, beginning in June, 1946. He will give a course of lectures intended principally for members of the staff but the course will also be available to graduate students for credit.

Dr. K. A. G. Strand, of the Sproul Observatory of Swarthmore College, has been appointed Visiting Associate Professor at the University of Chicago beginning October 1. Dr. Strand will be in charge of observational work in positional astronomy at the Yerkes Observatory and also at the McDonald Observatory of the University of Texas. He will be primarily engaged in photographic and visual observations of double stars.

Dr. Arthur Adel will be appointed Astronomer in Charge of Maintenance at the McDonald Observatory and Assistant Professor in the Department of Astronomy, beginning October 1, 1946.

Clyde W. Tombaugh, who is serving this year as Visiting Assistant Professor of Astronomy in the University of California, Los Angeles, delivered an illustrated lecture on "The Discovery of the Ninth Planet, Pluto," on March 28, 1946, before an open meeting of the local chapter of the Society of the Sigma Xi.

Dr. Harlow Shapley, director of the Harvard College Observatory and of many other scientific and non-scientific organizations, gave one of the principal addresses at the educational conference held at the University of Minnesota on April 23, 24, 25 in connection with the inauguration of Dr. James Lewis Morrill as eighth president of the University of Minnesota. During the two days Dr. Shapley spent in Minneapolis he was thoroughly busy with conferences and informal talks. Just before boarding the plane for the east Dr. Shapley at a joint dinner meeting addressed the Minnesota United Nations Committee and the Minnesota Branch of the American Association of Scientific Workers on the formation and progress of UNESCO and, informally, on the control of atomic energy.

The Rittenhouse Astronomical Society met with the Physics Club of Philadelphia, on April 12, 1946, in the Harrison Laboratory of Chemistry of the University of Pennsylvania. The speaker was Dr. George Gamow, Physicist, George Washington University, and his topic, "Origin of the Universe."

The Cleveland Astronomical Society

Dr. S. Chandrasekhar of the Yerkes Observatory, University of Chicago, addressed the meeting of the Cleveland Astronomical Society on April 5. His topic was "The Age of the Universe." Dr. Chandrasekhar first pointed out that not all parts are of the same age and thus cannot all be represented by a single value. To determine a time scale or unit for each member of the universe a lapse of time is selected in which some noticeable change has taken place. Such a unit for the human being for example might be 20 years.

The star cluster in the Pleiades was taken as an example. Two stars in this system pass each other on an average once in 10,000 years which results in a certain amount of deceleration. On occasion, however, the velocity of a star may be increased. The increase may be sufficient to cause the star to escape from the cluster. In this way the cluster may eventually disintegrate. For each star in the cluster, in three billion years its probability of escape is one-half. Three billion years was thus considered a good time scale for clusters like the Pleiades. The half-life period of clusters of spiral nebulae was given as 10 to 100 billion years, and 1000 billion years are needed to disrupt distant binary stars. The upper limit of the age of the earth as determined by the disintegration of uranium is around 2½ billion years. The average age for meteorites is older than that of the earth, perhaps seven billion years.

The speaker stated that the reason spiral nebulae are receding from us at speeds which increase with distance may be due to the fact that they were all together at the beginning and the swifter ones have moved out to greater distances because of their greater speeds. If traced backward to a time three billion years

ago they would all be in a single rather small volume. This date seems to indicate a fundamental instant for our universe. Perhaps it is the time of the common origin of all the members of our present universe, the speaker said, formed by the explosion of a single dense, hot star or a single super atom. A study of the uniformity of composition of the various objects in the universe and correlation of abundance and stability of the elements leads to a similar conclusion.

On the following afternoon, April 6, Dr. Chandrasekhar lectured to the Ohio Neighborhood Astronomers on "The Continuous Absorption Coefficient in Stellar Atmospheres." The writer was, unfortunately, unable to attend this interesting meeting.

HENRY F. DONNER, *Secretary.*
Western Reserve University, Cleveland 6, Ohio.

Astronomical Equipment and Government Surplus Materials

The Teachers Committee of the American Astronomical Society has investigated the procedures involved in obtaining Government surplus materials for educational purposes. These are summarized here for the benefit of those teachers of astronomy who have not already availed themselves of the opportunities offered in this manner to enhance the equipment of their student and research laboratories.

There are, and will continue to be for some time, opportunities to obtain at reduced prices telescopes, binoculars, cameras, photographic supplies, navigation equipment of all sorts, projectors, training films, and many other items that can be used with profit in the teaching of astronomy.

On March 25, 1946, a change was made in the manner of distributing much of this equipment; all materials will now be handled strictly through the regional offices listed below, the Washington offices of the RFC and the WAA controlling and standardization of prices for such materials but not the handling of them. Many universities have established their own agent to keep in touch with these regional offices and many of you may have already benefited from the sale of Government surplus properties. If you are a member of such an institution, you need only to make your needs known to this agent. If, on the other hand, your institution has not yet actively participated, it will be necessary for you, if you are interested in obtaining such equipment, to communicate with the regional office, preferably in person, and make your specific needs known.

In either case, you are requested, according to our advice from the War Assets Administration, to be as specific as possible in your requests. For instance, requests for "a camera" or "a telescope" are apt to be overlooked and more definite requests, say for "a telescope of 3-inch aperture" or "a 35 mm, F2.5 camera, shutter speeds up to 1/400 second" will be given preference.

We are also advised that the turnover of available equipment is rapid and that one must be ready to close a transaction quickly. For this reason, it is obviously impossible for the Teachers Committee to act as a clearing house or as a jobber for astronomy laboratories over the country. The responsibility for obtaining such equipment must rest directly with your institution and, specifically, with you as the interested party.

WAR ASSETS CORPORATION
WASHINGTON 25, D. C.
ASSOCIATE REGIONAL DIRECTORS, CONSUMER GOODS DIVISION

Bernard J. Braudis, Acting Associate Regional Director, War Assets Administration, Washington-Essex Building—5th Floor, 600 Washington Street, Boston 11, Massachusetts (Telephone: Lafayette 7500).

Frank L. Seymour, Associate Regional Director, War Assets Administration, 350 Fifth Avenue—62nd Floor, New York 1, New York (Telephone: Murray Hill 3-6800).

Joseph G. Dellert, Associate Regional Director, War Assets Administration, Lafayette Building, 5th and Chestnut Streets, Philadelphia, Pennsylvania (Telephone: Walnut 400).

Rowland D. Schell, Associate Regional Director, War Assets Administration, 704 Race Street, Cincinnati 2, Ohio (Telephone: Parkway 7160).

Fred McLauchlan, Acting Associate Regional Director, War Assets Administration, 209 South LaSalle Street, Chicago 4, Illinois (Telephone: Franklin 9430).

B. Leo Wilson, Associate Regional Director, War Assets Administration, 699 Ponce de Leon Avenue, N. E., Atlanta, Georgia (Telephone: Cypress 1961).

Hamilton Morton, Associate Regional Director, War Assets Administrtaion, P. O. Box 1407, Fort Worth 1, Texas (Telephone: 2-1285).

John E. Kirchner, Acting Associate Regional Director, War Assets Administration, Troost Avenue & Bannister Road, 95th Street, P. O. Box 1037, Kansas City, Missouri (Telephone: Delmar 3500).

John F. Hough, Associate Regional Director, War Assets Administration, Commonwealth Building, 728 Fifteenth Street, Denver 2, Colorado (Telephone: Keystone 4151).

Leland C. Dedo, Associate Regional Director, War Assets Administration, 30 Van Ness Avenue, San Francisco 2, California (Telephone: Underhill 2425).

Orrin C. Bradeen, Associate Regional Director, War Assets Administration, 2005 Fifth Avenue, Seattle 1, Washington (Telephone: Main 2728).

J. A. Fraser, Regional Director, War Assets Administration, Federal Reserve Bank Building, Cleveland, Ohio.

The regional offices are furnished with lists of materials as soon as they are declared available surplus. Tax supported institutions are high on the priority list and your needs will be taken care of first if you make them known! (If you are a veteran, you are in a favored position to make personal purchases.) We have also been advised by the War Assets Administration that "10c on the $1.00" bargains are exceedingly rare and for the most part, fair prices for surplus equipment are charged. However, in certain cases, striking savings can be made; this appears to be particularly true in the matter of training films and obsolete demonstration equipment.

J. A. Hynek, *Chairman*,
Teachers Commitee.